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- CLIMBING MOUNT HYDROGEN
- WHY SIMULATORS = SUSTAINABILITY
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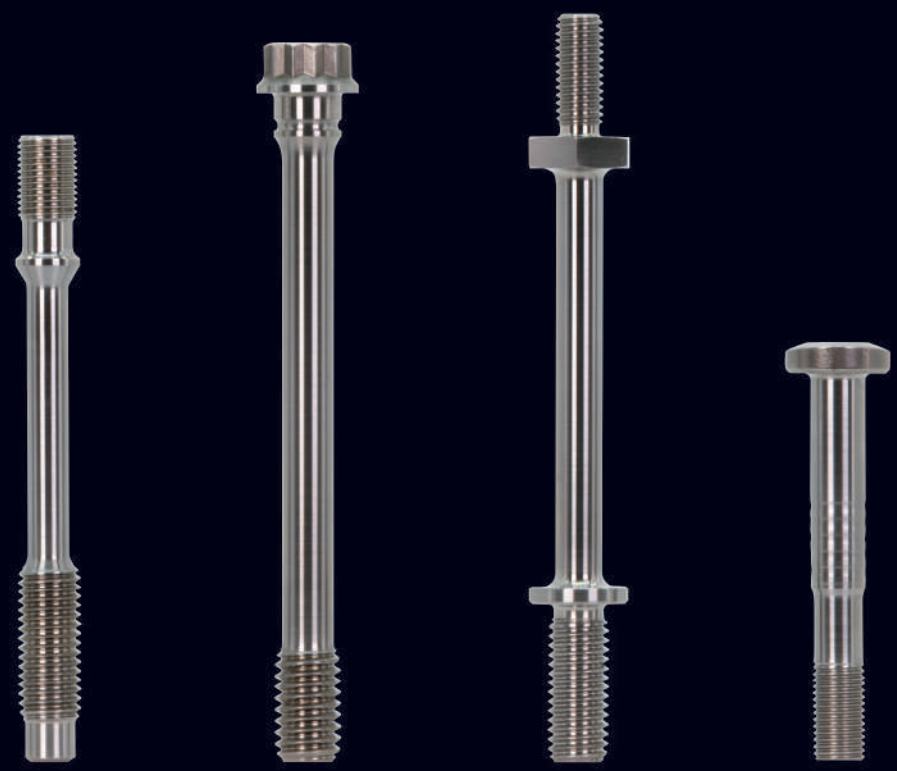

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"WE LOSE, WE LEARN"

"**HUNT** the Magic Bullet". It's got to rank as the least satisfying party game ever devised, hasn't it?

Especially when there isn't even a magic bullet to be found...

We all want a quick solution to difficult problems. Only human nature. And when it comes to confronting issues like the Climate Crisis and the intricacies of the energy transition, the search for that answer can be quite infuriating. Just ask all those delegates leaving the latest COP conference.

More than 55,000 people attended Baku's COP29, but they struggled for answers. So it is understandable that a few of the exchanges at the recent Race Tech World Motorsport Symposium, 'The Davos of Motorsport', were also quite challenging at times as some of the industry's key players debated possible routes through the landscape ahead.

There are a few fascinating avenues of research being followed at the moment, that is beyond question. But nobody is wasting their time in the quest for that one-size-fits-all solution because there isn't one.

BEVs, sustainable fuels, hybrids, hydrogen, we will need all these technologies. But their use will vary according to the industries, the applications, the regions, the weather, the infrastructure etc.

Are we trying to decarbonize motorsport? Yes, but I think the consensus from those present at the Royal Automobile Club, Pall Mall, last month was that it is more important for us to use our talents to help develop the ecosystems in which these new technologies can flourish in wider society.

I have confessed it before, that I was once a WMS sceptic. My life would certainly be a lot easier had I stayed one! I am super-impressed by many of the technical developments that the delegates bring us up to speed with at the symposium. But, above all, I am lost in admiration for the attendees' sheer passion, the determination, their undiminished drive to learn more, no matter how vast their achievements may already be.

Maybe that desire is rooted in the motorsport mindset. As David Salters, President of Honda Racing Corporation, suggested in his excellent presentation, "We lose, we learn."

This year's event was, well, amazing. That was down to the people who attended. I hope you all found it useful.

A final flurry of thanks, to Ulrich (Baretzky), Pat (Symonds) and John (Iley), who were, as ever, giants. And to Soheila Kimberley, whose own seemingly indefatigable drive not only created the WMS in the first place, but has propelled it throughout 20 years. We surprised her with an award of her own at the Awards Evening. It left her speechless.

Those of you who know Soheila well will appreciate what a cheap shot it would be for me to say anything more!

Mark Skewis
EDITOR

WHY CLIMBING "MOUNT HYDROGEN" IS NOT ENOUGH

Toyota has made remarkable breakthroughs racing with liquid hydrogen, but has discovered the climb gets tougher near the summit of the mountain. By **Mark Skewis**

TOYOTA'S pioneering work with a liquid hydrogen-powered racecar was recognised in London last month with the award of the Race Tech Powertrain of the Year accolade. But GAZOO Racing Company President Tomoya Takahashi has sounded a cautionary note, admitting that every step forward with this technology is revealing new challenges that must be conquered.

With Le Mans transitioning to hydrogen and the FIA championing a switch from gaseous to liquid hydrogen, developing a racecar and supporting infrastructure to survive at -253 deg C has become motorsport's holy grail. Toyota has not just assessed the feasibility of the technology, but has now been racing with it in Japan for two full seasons, making huge strides forward.

Developing hydrogen engines has often been compared to climbing a mountain, with the question, "What (mountain) station has been reached?" asked each year.

President Takahashi views the development of the technology for commercial vehicles as the first peak that must be achieved, but is well aware that the trek to passenger vehicles requires a further daunting climb. "Until now, we've been climbing Mount Hydrogen," he said. "But what the Fuji 24-hour race keenly brought home is that, in order to make ever-better cars, we need to conquer various

BELOW The new hydrogen tank's custom elliptical shape (left) means it can hold 15 kg of hydrogen, while the old one (right) holds just 10

All photos: Toyota

Plan to use boil-off gas to improve efficiency of liquid hydrogen

TOYOTA has shown a new concept model that utilizes boil-off gas from liquid hydrogen as energy.

Although it is still in the concept stage, if realized, this technology is expected to improve the energy efficiency of the entire liquid hydrogen system. Toyota is therefore looking to form partnerships that will help make this technology a reality.

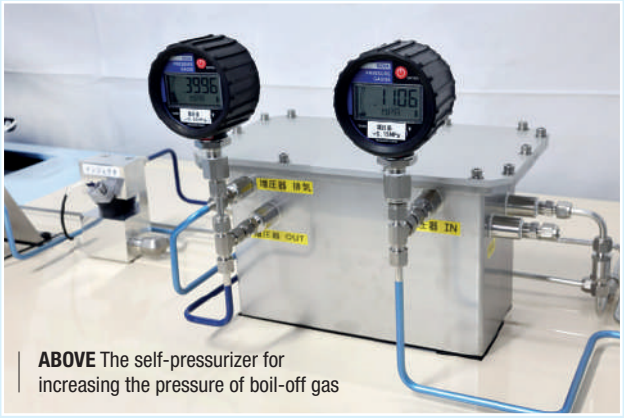
Liquid hydrogen has a higher density than gaseous hydrogen. This allows for more hydrogen to be stored in a tank of the same capacity but presents an issue of boil-off, where the liquid hydrogen fuel stored in the tank evaporates due to natural heat that enters from outside.

Until now, the boil-off gas (vaporized hydrogen) generated in the fuel tank while driving has been released into the atmosphere without being used.

One concept Toyota is working on is to produce reusable fuel by sending boil-off to a self-pressurizer (a device that increases pressure without relying on external energy). Boil-off gas can be converted back to usable hydrogen fuel for the engine by applying pressure, but increasing the pressure sufficiently usually requires energy such as electricity. The self-pressurizer it is developing uses the pressure of the boil-off gas to increase pressure by two to four times and produce reusable fuel without using any additional energy.

During the pressurization process for reusing boil-off gas, a certain amount of surplus boil-off gas is still released. Toyota has looked at feeding this into a small fuel cell package it has developed, using a chemical reaction to generate electricity. The electricity can then be used to power parts like the motor for the liquid hydrogen pump. If realized, it will be possible to supplement electricity equivalent to the amount generated by the alternator (small generator) from boil-off gas, leading to an improvement in energy efficiency.

Boil-off gas not used in the electricity generation process will be converted into water vapour through a catalyst and safely released outside the vehicle.



ABOVE The self-pressurizer for increasing the pressure of boil-off gas

other mountains beyond this peak.

"I think it's clear that reaching a single summit is not going to deliver great cars to our customers."

Saving the ICE

Unconvinced that the stampede towards BEV technology is the only way to battle the climate crisis, Toyota is part of a Japanese consortium developing hydrogen combustion and sustainable fuels that could throw the imperilled Internal Combustion Engine a lifeline.

The car giant has begun public road testing of a hydrogen-powered HiAce in Australia, saying it is "two-thirds of the way toward commercialization."

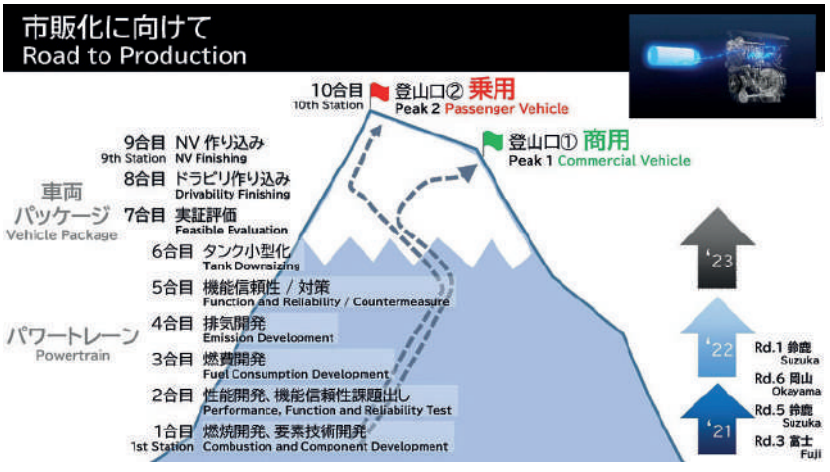
In Japan, it has been racing an experimental H2 Corolla in the Super Taikyu series. It made the switch from gaseous to liquid hydrogen in 2023, successfully completing the Fuji 24 Hours in the process.

Last year, its Rookie Racing-entered GR Corolla H2 Concept completed 358 laps (1,634 km) on liquid hydrogen, in a world-first for the technology. At this year's race the car spent nine hours in the pits due to brake system problems, finishing with 332 laps (1,515 km). It has revealed, however, that despite falling short of last year's distance, there were several reasons for encouragement.

To date, the reliability of the liquid hydrogen pump, which has to operate at very low temperatures, has been the project's Achilles Heel. At last year's race this necessitated two stops, of four and three hours respectively, to change the pump. But this year the introduction of a new dual-drive crank mechanism transmitted the driving force to both sides of the crank, alleviating uneven loadings and torsion in the components and boosting durability.

The modifications had a big effect, completely eliminating pump failures in follow-up testing. Although the car had a lengthy pitstop during the race, this had nothing to do with pump durability. ▶

BELOW Toyota discovered that it might not have been as high up the development mountain last year as it believed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Tank revolution

Extracting the required stint length for an endurance race from a tank of hydrogen is one of the biggest issues facing plans to transition the Le Mans 24 Hours to the "magic molecule". Few doubt that this worry is behind the FIA's preference for liquid hydrogen.

With Toyota likely to be the first to compete in the endurance classic with hydrogen, all eyes have been focused on the Japanese development team's efforts to increase the Corolla's range per hydrogen refuel.

Having notched up 12 laps (approx. 54 km) at the Fuji 24 Hours a year earlier, the team extended this to 20 laps (approx. 90 km) at last season's final round. For the 2024 race, they set their target at 30 laps (approx. 135 km), a further 50% increase. They managed to clear this bar, clocking 31 laps on a full tank – on a par with cars running on gasoline.

This progress was made possible by changing the fuel tank shape to increase capacity. A new oval shape made more efficient use of the space inside the vehicle, enabling it to carry 1.5 times more liquid hydrogen fuel than last year.

For gaseous hydrogen, tanks are generally cylindrical to ensure that forces are distributed evenly along their walls, allowing them to withstand high pressures of 70 MPa.

By contrast, liquid hydrogen can operate at much lower pressures. With a tank pressure of less than 1 MPa, theoretically, there is no need to stick with cylindrical shapes.

Last year, the team opted to start with a cylinder on the grounds of safety, because as yet there are no regulations for carrying liquid hydrogen. This season's elliptical tank was approved after consulting the national government and relevant agencies.

ABOVE & BELOW Remarkable improvements have been made in terms of range, reliability and carbon capture

RIGHT A dual-drive gear set has alleviated torsional forces that influenced the durability of the fuel pump

While turning a circle into an oval may look simple, "This is a very big step forward, in terms of both legislation and R&D," noted GR Vehicle Development Division Project General Manager Naoaki Ito.

Another area of evolution is a revamped CO2 capture system, originally introduced in the final round of last season's series.

A filter coated in a CO2 adsorbent developed by Kawasaki Heavy Industries is used to catch carbon from the atmosphere (adsorption phase). Hot air is then passed through to release the CO2 (desorption phase), which is then dissolved into a recovery liquid (capture phase).

Last year the mechanics manually replaced the adsorption and desorption filters during each pit stop. This time, the two filters have been combined into one, eliminating the task of replacing them.

By expanding the filter's surface area, the new system captures 4 grams of CO2 per lap, double that of the previous arrangement.

So where is Toyota on the hydrogen mountain now? GR Vehicle Development Division Project General Manager Naoaki Ito said, "The hydrogen engine's base camp has been made, so the next mountain we have to climb has come into view..." RT

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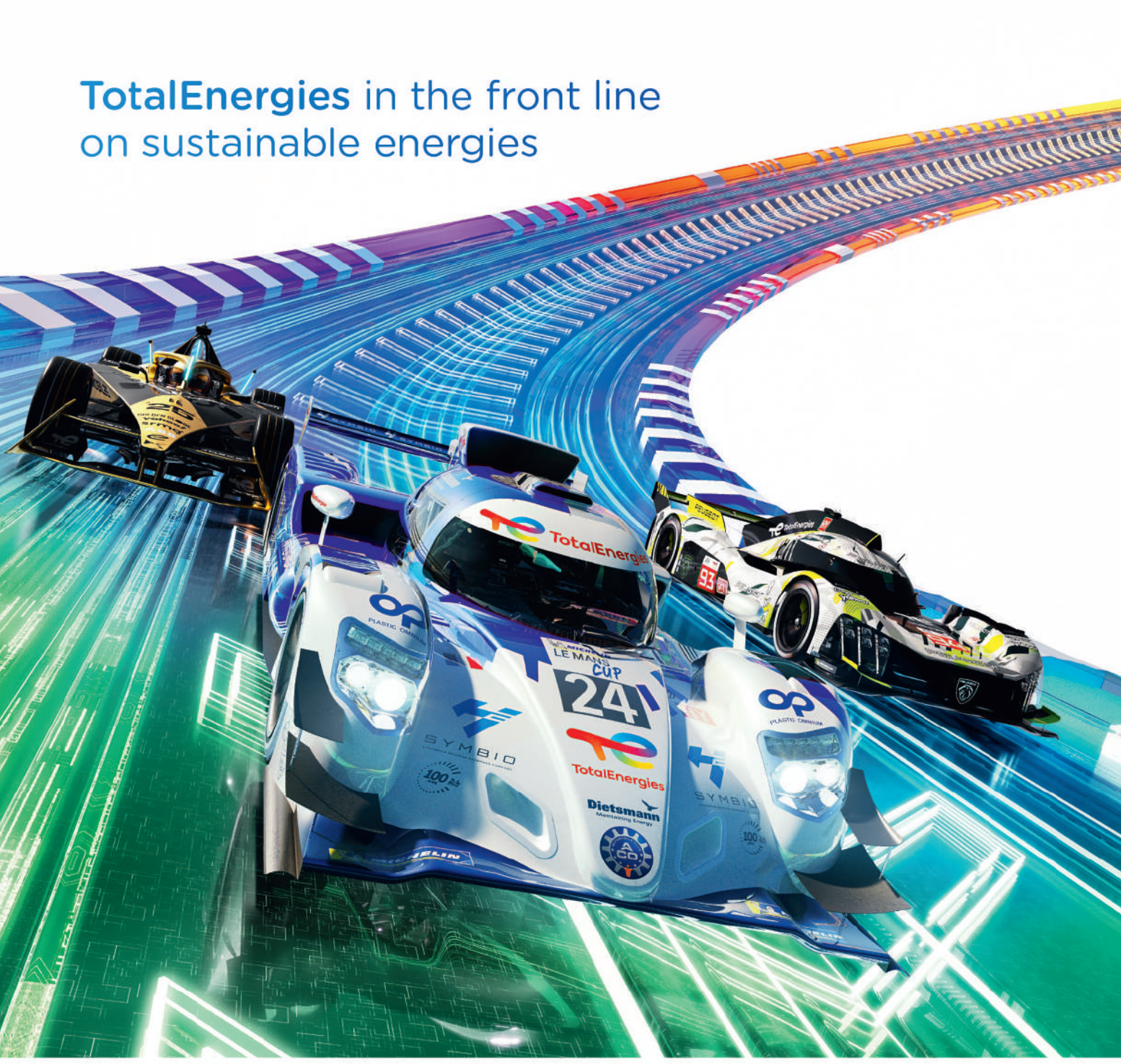

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Toyota, McLaren Racing, Bosch Motorsport and Ru-Bix Advanced Materials win Race Tech awards

TOYOTA, McLaren Racing, Bosch Motorsport and Ru-Bix Advanced Materials scooped the honours at the Race Tech technical awards, held last month at The Royal Automobile Club, Pall Mall, London, on the 20th anniversary of the magazine's World Motorsport Symposium.

The awards recognise remarkable innovation and game-changing technologies as well as ground-breaking motorsport technology that enables a positive impact on the environment. They were determined by a judging panel of industry experts representing diverse motorsport engineering disciplines.

The symposium's theme of 'Speed with Sustainability' was reflected in the coveted Race Powertrain of the Year award, which Toyota won for its pioneering work on an experimental liquified hydrogen powertrain it races in Japan's Super Taikyu series.

This season's development work on its inline three-cylinder engine has reaped impressive improvements to reliability, range – thanks to its introduction of an elliptical-shaped fuel tank – and CO2 capture.

The award was received by Pascal Vasselon, Vice President of TGR Strategic Motorsport Development, where he focuses on hydrogen technology and carbon neutrality.

"We have a very talented development team in Japan and I am accepting the award on their behalf," said Vasselon. "It is a visionary programme based on the belief, passed down from the very top of the company, that motorsport must be relevant and useful to society: it has to lead decarbonization."

Toyota beat off fierce competition from IndyCar, which introduced a supercapacitor-based hybrid system this season, and Bosch Engineering, whose hydrogen-combustion engine ran a demonstration lap at Le Mans.

ABOVE The WMS award winners with the event's co-chairmen

Dino Toso Racecar Aerodynamicist of the Year Award

Aerodynamic development is king in Formula 1 and the judges believed nobody had a better claim to the crown this year than a rejuvenated McLaren F1 Team.

It had the third fastest car in the first five races of the season. But a big upgrade in Miami, which left almost no aero surface untouched, made the MCL38 competitive overnight and ignited a spectacular quest for the team's first manufacturers' title since 1998.

Accepting the Dino Toso Racecar Aerodynamicist of the Year award on behalf of the McLaren Racing aerodynamics team, Giuseppe Pesce, Director of Aerodynamics, said: "It's been an incredible journey, to go from pretty much the back of the field to the front. Thank you on behalf of the entire aerodynamics department."

Other nominations included Ferrari's 499P, for its second successive win at the Le Mans 24 Hours, and Porsche's IMSA and World Endurance Championship-winning 963.

William Kimberley Green Tech Award

Technical innovation will be the key to the world meeting its ambitious green targets and the winner of the William Kimberley Green Tech award illustrated that point precisely.

Norfolk, UK-based Ru-Bix Advanced Materials is one of the companies leading a new wave of responsible manufacturing in high-performance sports. This year it improved its flagship Halo-S tooling board by incorporating significant levels of bio-carbon content and recycled plastic, resulting in a tooling material with a very low global warming potential (GWP). This unique material has met with great enthusiasm from engineers based in the composites industry.

"People talk a lot about sustainability, but it is something that we as a company are passionate about," said Barrie Colvin, Technical Director, Ru-Bix Advanced Materials, accepting the award.

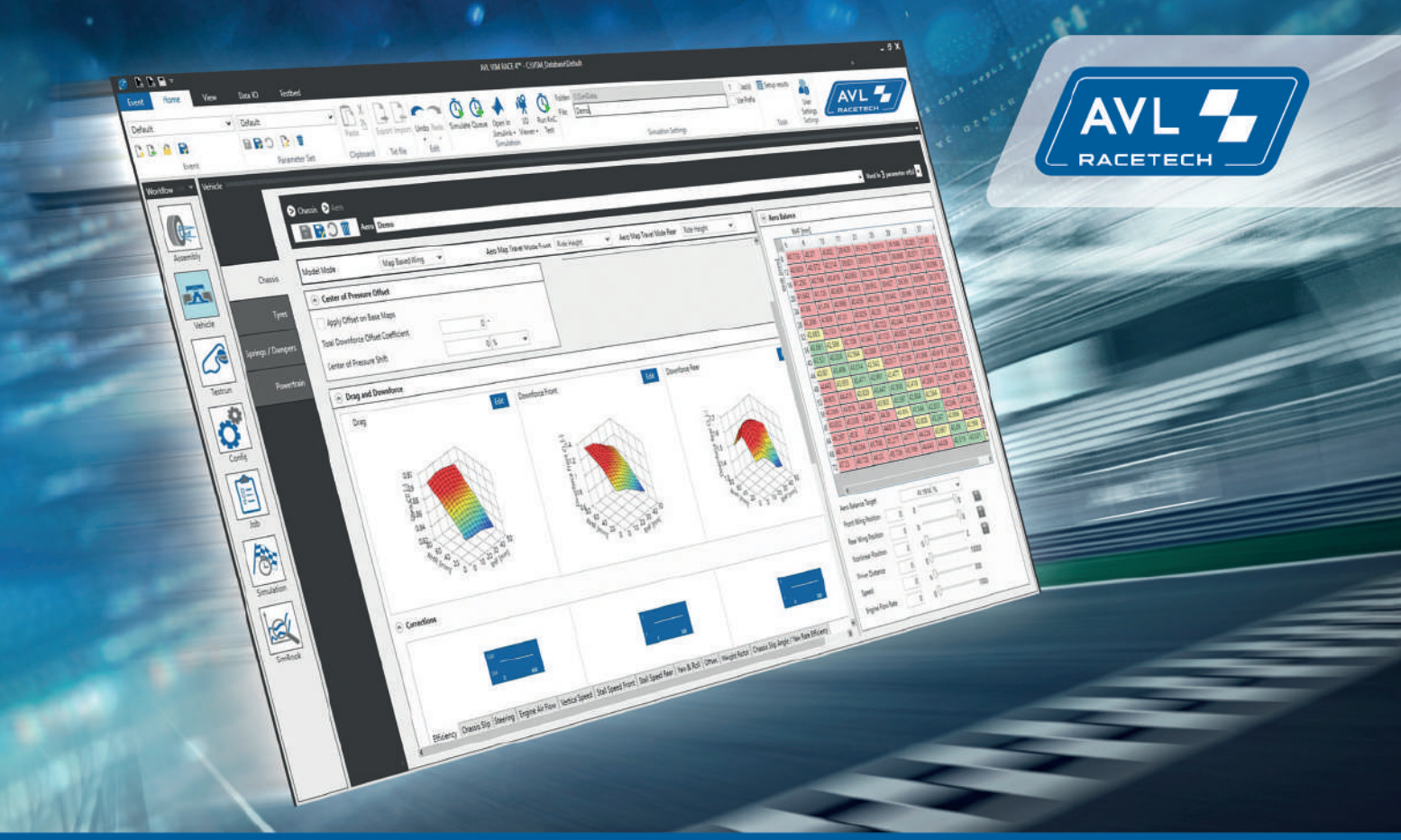
Don Burgoon Most Innovative New Motorsport Product of the Year Award

The Don Burgoon Most Innovative New Motorsport Product of the Year Award was won by Bosch Motorsport for its development of a pioneering electronic braking system that enables disabled racecar drivers to brake using hand controls instead of foot pedals.

Asked for help by Robert Wickens, who was left paralyzed by an accident in IndyCar in 2018, Bosch adapted its existing electronic brake system (EBS) module, which is used in sportscar racing. It replaces a series of mechanical linkages that physically operated the car's standard brake pedal, eliminating delays and friction from the existing mechanism.

"To develop our system for a different application is what systems engineering is all about," said Michael Muerlebach, Director, Bosch Motorsport. "To see Robert's focus, his passion to return to racing, gave our entire development team a buzz. This is a story that gives me goosebumps."

There was also a surprise for the symposium's creator, Soheila Kimberley. She usually shies away from the limelight but her awards committee departed from the script to present her with a lifetime achievement award for having organised the event, often dubbed The Davos of Motorsport, for 20 years. RT



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"Biggest fibre innovation in 50 years" brings game changing tech to F1

AERO Tec Laboratories (ATL), the leader in safety fuel systems and fluid containment technology, is collaborating with DuPont to bring a "game changing" new material to the racing industry.

The collaboration begins with the launch of a new fuel bladder for the introduction of sustainable fuels to Formula 1 in 2026.

The new material, Kevlar EXO, builds on the legendary performance of Kevlar – quite literally – by adding a third monomer to the existing two in Kevlar. The enhanced molecular alignment of Kevlar EXO can, says DuPont, provide levels of strength and durability never before seen in an aramid fibre.

"The first time we tested Kevlar EXO, we knew it was going to be game changing. We have not seen any new innovation or technology like this in fuel bladders in decades," said ATL CEO Giles Dawson.

"With the weight savings Kevlar EXO enables, we are excited to see how we can further collaborate to bring even more innovative FIA-certified products to the industry. Our development focus is for the 2026 regulations where every race car will utilize fully sustainable fuel. This innovative new material has provided several benefits in our development efforts."

DuPont Kevlar EXO was first introduced to the life protection market in April 2023, enabling body armour with an unprecedented combination of flexibility and lightweight strength from an aramid fibre. In fuel bladders, it significantly enhances performance by providing superior resistance to impact and abrasion. This improvement in strength allows for the development of lighter yet highly reliable fuel bladder systems, meeting stringent FIA requirements while reducing overall weight by more than 20%.

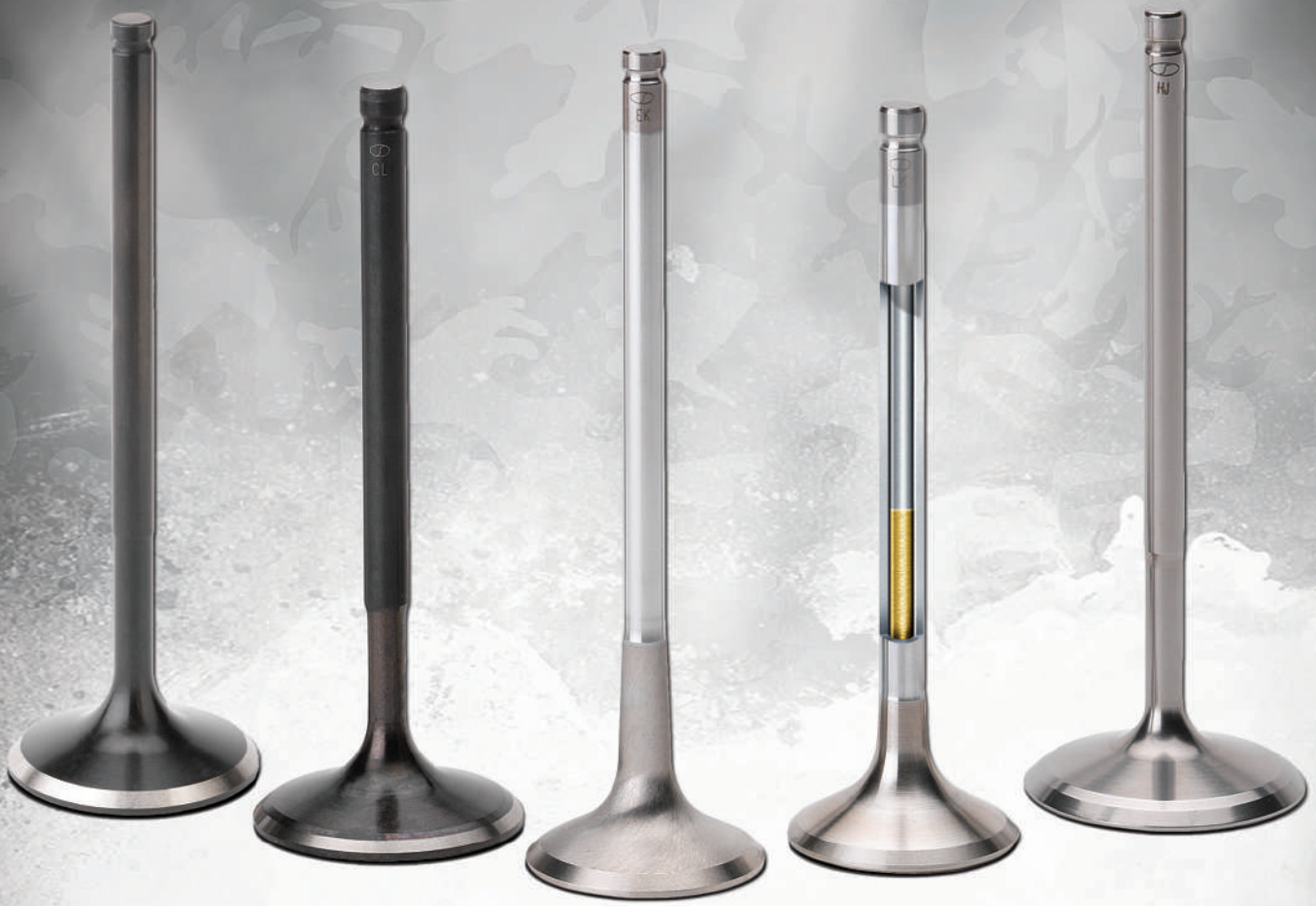
Drawing on their combined knowledge and expertise in safety, design, racing industry certification, mechanical testing capabilities, and research and development, DuPont and ATL worked together to ensure the new fuel bladder complies with FIA safety standards. This successful collaboration has ultimately led to the transformation of the way F1 fuel bladders are constructed.

After the success of the initial programme, DuPont and ATL plan to expand their collaboration to explore how they can apply the learnings from F1 fuel bladders to other racing industries such as NASCAR, IndyCar, and Le Mans.

"This collaboration goes beyond the fact that Kevlar EXO is DuPont's biggest fibre innovation in more than 50 years. It also further proves the variety of game changing applications the material can have outside of military and defence, allowing us to take a front row seat in new industries," said Jill Clements, DuPont Global Commercial Leader for Kevlar EXO . "The performance we're seeing from Kevlar EXO has enabled us to look to new markets, applications, and industries, and we're excited about what's next." RT

BELOW F1's switch to sustainable fuels is being aided by DuPont's new wonder material

SUPERTECH



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General Motors to enter F1 in 2026

THE acrimonious and long-running dispute between Formula 1 and Andretti has been resolved in a win-win solution: Formula 1 bags the engine manufacturer it craves to fill a Renault-shaped hole, without having to cave and officially admit Andretti to the exclusive club; and the US squad finally gets an entry for 2026.

The entry is for a 'new' team, of course, GM's luxury Cadillac brand, rather than anything to do with the US racing dynasty. Just to demonstrate the distance between the two, GM's partner in the venture will be TWG Global – which owns and operates Andretti Global – and 1978 F1 World Champion Mario Andretti will be a consultant. The team will also inherit the work that has been going on behind the scenes for over a year on the long-lead items designed for the new car.

Greg Maffei, president and chief executive officer of F1 commercial rights holder Liberty Media, said: "With Formula 1's continued growth plans in the US, we have always believed that welcoming an impressive US brand like GM/Cadillac to the grid and GM as a future power unit supplier could bring additional value and interest to the sport.

"We credit the leadership of General Motors and their partners with significant progress in their readiness to enter Formula 1."

It is reputed that GM and TWG will pay an anti-dilution fee of $450m (£358m) to ease the existing F1 teams' unhappiness at this outcome – significantly larger than the $200m figure dictated by the existing F1 rules.

This will be split between the existing 10 teams as compensation for their loss of prize money as a result of F1's income now being split 11 ways rather than 10. The teams receive between them in the region of 63% of F1's income.

The Cadillac team will use a customer engine, probably from Ferrari, until its own PU comes on stream for 2028.

"As the pinnacle of motorsports, F1 demands boundary-pushing innovation and excellence. It's an honour for General Motors and Cadillac to join the world's premier racing series, and we're committed to competing with passion and integrity to elevate the sport for race fans around the world," said GM President Mark Reuss. "This is a global stage for us to demonstrate GM's engineering expertise and technology leadership at an entirely new level."

Michael Andretti, who co-founded the team that bears his name, is no longer involved after stepping down from his role in Andretti Global in September.

The former IndyCar and F1 driver was viewed as a divisive figure who had rubbed people up the wrong way with what was seen to be his confrontational approach to trying to secure an entry.

F1 is facing an investigation from the US department of justice into its decision to reject Andretti's initial entry.

Michael's father, Mario Andretti, the last American F1 World Champion, will serve as a director on the new team's board. He said he was "beyond fortunate" to have a role "offering advice, inspiration, friendship anywhere I can."

"My first love was Formula 1 and now – 70 years later – the F1 paddock is still my happy place," said Andretti. "To still be involved at this stage of my life – I have to pinch myself to make sure I'm not dreaming." RT

Cosworth expands Antares ECU family

COSWORTH has launched the Antares 4 and Antares 6 ECUs, the first additions to its industry-leading Antares ECU family.

Engineered with a balance of cost-efficiency and high performance, the Antares 4 and Antares 6 models bring the advanced capabilities of the flagship Antares 8 to a wider array of motorsport applications.

Developed for flexibility and affordability, the Antares 4 and 6 pack the power of a top-tier ECU into a streamlined, cost-effective solution, perfect for budget-conscious applications across ICE, hybrid and EV platforms.

Both new ECU units come equipped with sophisticated, out-of-the-box control features such as multi-pulse and stratified GDI control, active torque management and FIA-compliant real-time PPU and BOP control.

For teams seeking advanced customisation, Cosworth's real-time embedded software generation platform enables the development of bespoke control algorithms within the MATLAB Simulink environment. This allows teams to deploy complex powertrain and chassis control algorithms, signal processing routines, dynamic models and ultra high-speed data processing within the development toolchain.

Teams can also develop strategies utilising Simulink Neural Network blocks to create the ultimate machine learning for driven traction control.

"Cosworth is dedicated to pushing the boundaries of motorsport engineering, and the Antares 4 and 6 demonstrate our commitment to making high-tech solutions accessible across all levels of competition," said Stef Balkowiec, Managing Director at Cosworth Electronics. "By expanding the Antares family, we're equipping teams with the precision and power of Cosworth technology in a more adaptable budget-conscious package." RT

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Japanese consortium renews hydrogen Dakar quest

A CONSORTIUM of Japanese manufacturers, the HySE (Hydrogen Small mobility & Engine technology Association), will return to the 2025 Dakar Rally's "Mission 1000" contest, which will be held in Saudi Arabia in January 2025, with the HySE-X2.

"Mission 1000" is the experimental category, trialled last year, which invites vehicles using next-generation powertrains in the quest for carbon neutrality.

HySE consists of Kawasaki Motors, Suzuki Motor Corporation, Honda Motor Co., Yamaha Motor Co., Kawasaki Heavy Industries, Toyota Motor Corporation and the DENSO Corporation.

It participated this year with its hydrogen engine-equipped HySE-X1 buggy to identify potential issues with small mobility that are yet unknown. HySE-X1 kept running through the final day and came in fourth position in the category.

ABOVE An evolution of the HySE buggy will tackle Dakar's experimental class

This time, its HySE-X2 will feature an evolution of the engine and chassis, in order to tackle new technical challenges like increasing output in the high revolution range, improving fuel consumption at the middle range and increasing capacity of the hydrogen tank.

The 1,250 kg buggy has a 998 cm^3 displacement engine. Its spec is: liquid-cooled, 4-stroke, inline four-cylinder, supercharged/DOHC 16 valves.

Where the HySE-X1 featured three hydrogen tanks, each with an internal pressure of 70 MPa, improvements to the chassis layout have enabled the installation of a fourth 7.2 kg tank.

Daichi Kai, Team Manager of HySE Dakar 2025 project, said: "We would like to contribute to the establishment of technologies for the small hydrogen mobility engine, by verifying the effects of the countermeasures for technical issues found with HySE-X1 this year and by challenging more severe performance area of the engine." RT

BrightLoop joins MissionH24 as tech partner

BRIGHTLOOP, a specialist in high-performance DC-DC converters, has joined the MissionH24 program and will equip its forthcoming H24EVO fuel cell prototype.

As a technical partner working in a variety of industries, BrightLoop shares the strategy of decarbonization and more sustainable racing pursued by the Automobile Club de l'Ouest and H24Project, the MissionH24 partners.

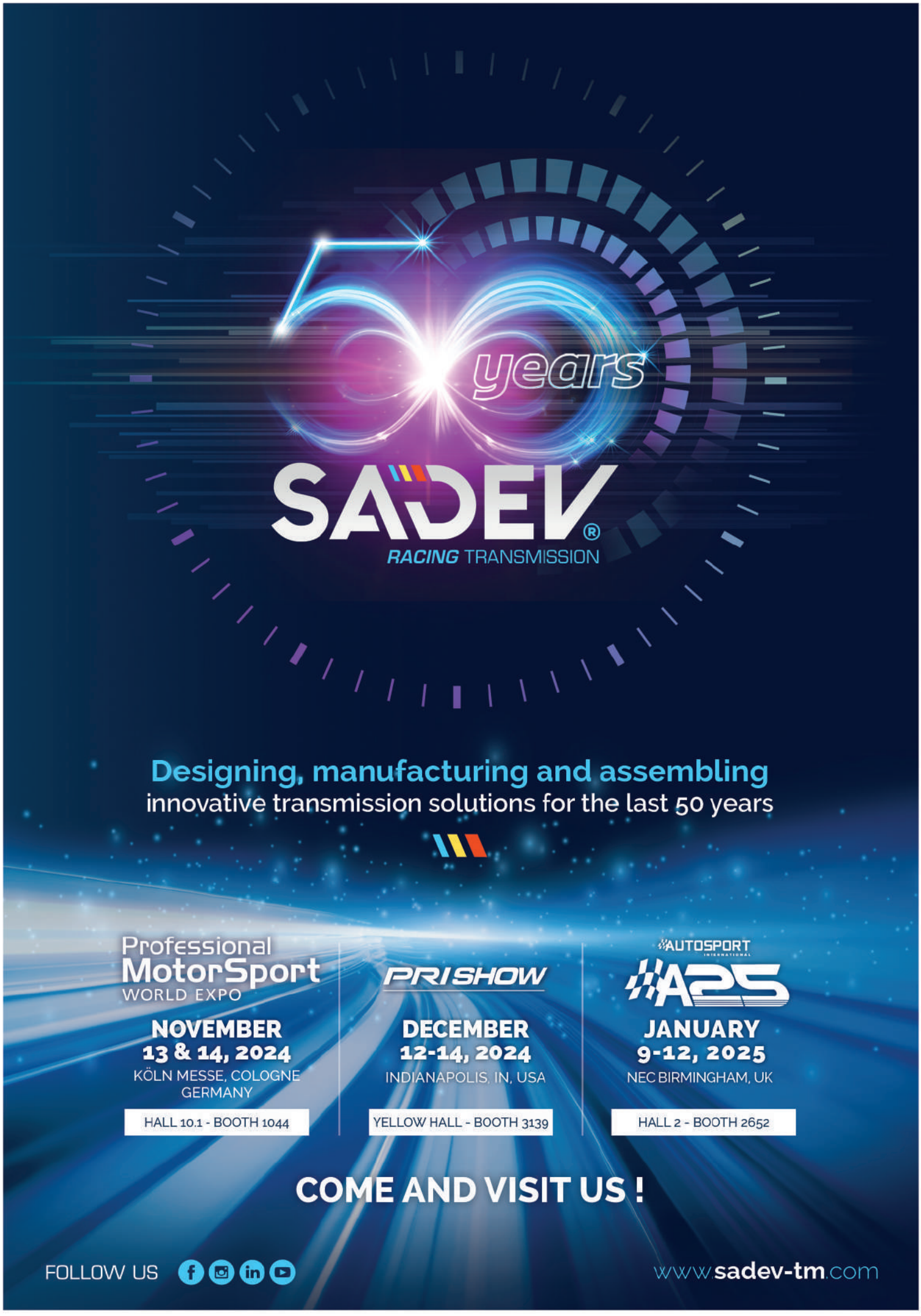
The company offers adaptable converters capable of managing all power flows, both AC and DC, positioning itself as a key partner for players in the energy transition.

The technology developed by BrightLoop enables intelligent management of power flows while offering unmatched compactness and power density, thereby optimizing space, energy efficiency, and control. This specification corresponds in every respect to the wish-list of the operating team of the future H24EVO.

Prior to its involvement in hydrogen racing, BrightLoop carved out a reputation in racing circles by supplying DC-DC converters of unique size (power density) and modularity to teams competing in Formula E, IndyCar and Extreme E.

This technical partnership will see members of BrightLoop integrated into MissionH24 for the first test sessions of the H24EVO. RT

RIGHT BrightLoop's expertise will help drive the MissionH24 project forward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Lifeline Fire & Safety Systems acquires S.P.A Design

LIFELINE Fire & Safety Systems Ltd has acquired the assets of S.P.A Design UK, a company long established in the field of fire suppression, motorsport services and products.

The deal was achieved through Lifeline's holding company, Hillcrest Technologies Ltd, and will secure enhanced distribution of its motorsport products.

By acquiring the S.P.A business, Lifeline will be able to consolidate its position as the leading global manufacturer of motorsport safety products while also gaining access to new markets in motorsport, defence and the niche vehicle sector.

Managing Director and owner of Lifeline, Jim Morris, commented: "I have always held high regard for S.P.A Design, having started my own career with S.P.A over 35 years ago. Bringing the S.P.A Design brand into the Lifeline group means we can build on the excellent foundations created by Richard Barnes, the founder of S.P.A Design, to further develop our product range and markets in line with our growth strategy."

Richard Barnes added, "Having known Jim when he worked for us in the early '90s, developing our first range of fire suppression products, it seems very fitting that I should pass on the baton to Jim and his team. I know the brand I created will be in safe hands and look forward to seeing it further grow and develop." RT

ABOVE Lifeline recently released Zero EV, the latest in electric fire suppression

F1 to introduce cooling device for extreme heat

FORMULA 1 is to introduce a device to cool drivers when conditions become too extreme in hot weather.

The move, which from next season will mandate a "driver cooling kit" when a heat hazard is declared, is a response to last year's Qatar Grand Prix.

Drivers complained after the race in the Gulf state last October that conditions were "beyond the limit".

A number of drivers needed medical attention for either dehydration or heat exhaustion after a race run in high temperatures and humidity.

Alpine driver Esteban Ocon said he had vomited in his helmet.

The new cooling system involves a series of measures all aimed at reducing the temperature in the cockpit when conditions could lead to heat-related medical concerns. These include a method of blowing cool air on the drivers, possibly using heat exchangers, and increasing cooling apertures in parts of the car around the cockpit.

The introduction of the device comes after what the FIA described as "encouraging test results" after a trial in Mexico.

The initial idea was for a form of air-con unit, but Lewis Hamilton dismissed the idea when quizzed earlier this year. "This is Formula 1," the seven-time world champion said. "It's always been like this. It's tough in these conditions, especially when you go to places like Qatar and Singapore. But I don't think we need an AC unit in the car.

"We're highly-paid athletes. And you've got to train your arse off to make sure you can withstand the heat, ultimately." RT

LEFT A new kit under development will aid the drivers

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Three strikes and out for WRC hybrids

THE end of the World Rally Championship's love affair with hybrid technology was sealed by an FIA World Motor Sport Council e-vote last month – but its root cause was scattered in the ashes of a fire in a Kent field last July.

Fire suppression has been one of the biggest challenges thrown up by the electrification of motorsport. The issue was highlighted when a battery ignited during charging at Lydden Hill's round of the World Rallycross Championship.

At the time, the blaze engulfed two cars, bringing a premature end to the weekend and blighting the remainder of the series. Nobody realised its ferocity would ultimately turn world rallying's hybrid dream to ashes too.

Green pathway

Although Citroen had experimented with a hybrid rally car as long ago as 2009 – it featured a 990-cell Lithium-Ion battery and a 125-kW electric motor, but played havoc with the C4's weight distribution – the technology wasn't introduced to the WRC until 2022. To great fanfare, a spec unit, along with the use of sustainable fuel, was billed as the pathway to a greener future.

But as with the British Touring Car Championship, which will also abandon hybrid technology from the start of the 2025 season, the cost, complexity and weight of the hybrid system has always been an issue.

The WRC's three manufacturers had been reluctant to abandon the series' green messaging, but the issue came to a head at Acropolis Rally Greece in September when the hybrid supplier, Compact Dynamics, introduced new user guidelines. It stipulated that if the 130-kW hybrid unit suffered three shock errors over 15G or one over 25G, it should be stripped apart and sent back to the supplier for a full repair.

Prior to this development, hybrid units could be reset on site during a rally. The alarm was effectively overruled, and the unit was free to continue in service.

So why the change of heart? Unfortunately, suppliers and rule-makers alike had been spooked by the complex investigation into the incident at Lydden Hill, when a battery aboard a Special One Racing-run Lancia Delta caught fire while its electric battery was charging. Kreisel, the manufacturer of the full powertrain in World RX, also provides the same 3.9 kWh battery in the hybrid system that Compact Dynamics supplies to teams in world rallying.

Hence the sudden decision to enforce the guidelines for units to be stripped and inspected after suffering three shocks over 15G.

Teams believed the change would have significantly raised hybrid unit repair costs, with the hybrid systems also potentially being out of action for months before they could be returned to the pool of working units.

"It is not a request to remove it for what it is, it is a request to remove it because we can't actually repair and run them at an economic price for M-Sport," said M-Sport team principal Richard Millener of his team's objections to the system. "We are talking a few extra million euro to do it and that is not something we can deal with."

Hyundai has embraced electrification on road and track, and is about to enter the World Endurance Championship, using a spec hybrid unit in its powertrain, in 2026. But Hyundai motorsport president Cyril Abiteboul admitted the rallycross fire had influenced the manufacturer's pragmatic approach to the WRC crisis.

"We always believe in the electrification of motorsport, electrification of WRC, but what matters the most is the sustainability of the sport and the stability of the sport, rather than anything else," he commented.

"We need cars, we need a stable technology, a technology that doesn't create negativity. Because right now when we talk about hybrid, it's more in negative terms than in positive terms. So that's absolutely the opposite of the desired effects."

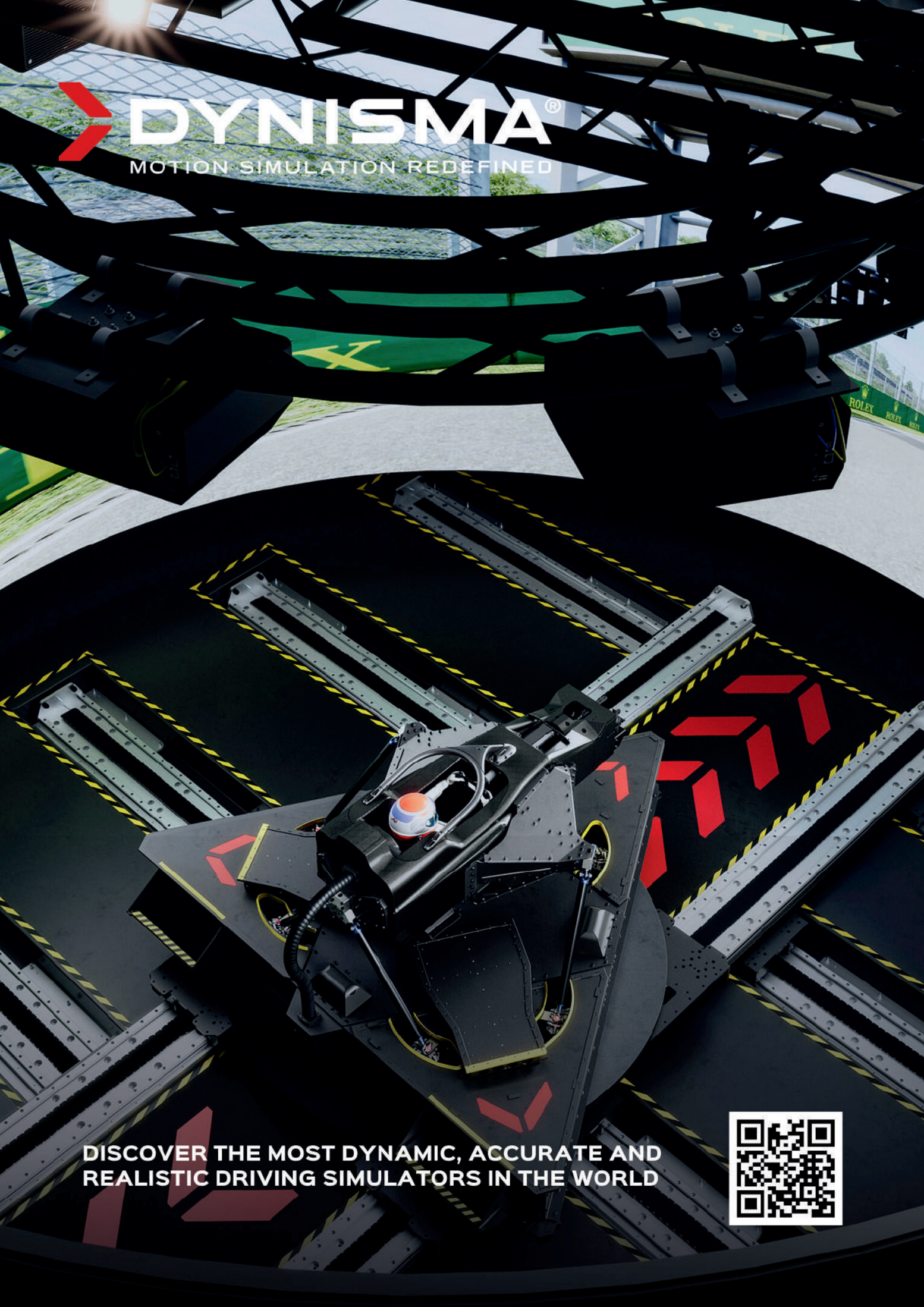
The plug-in hybrid will be abandoned from the start of 2025. The minimum weight of Rally1 cars will be lowered from 1,260 kilograms to 1,180 kilograms and the air restrictor size reduced from 36 mm to 35 mm to maintain an equivalent power-to-weight ratio between the 2024 and 2025 vehicles.

Reprieve

The WRC hybrids were already enjoying a stay of execution. It had been revealed back in February that the systems would be abandoned for 2025 when the FIA's working group announced its plans for the future direction of the sport. But the system was granted a reprieve when the manufacturers kicked back against the proposed changes, demanding rule stability until the end of the current rule cycles in 2026.

Ultimately, though, the WRC's failure to entice any new manufacturers to join forced everyone's hand. When the decision came down to the choice of losing the hybrid system or losing one of its three remaining squads, there could be only one winner... RT

BELOW Rally1 cars will no longer use the existing plug-in hybrid units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Court-battling NASCAR teams to race on in 2025

FEARS that NASCAR Cup Series teams 23XI Racing and Front Row Motorsport would not be able to compete in the 2025 championship, after they filed an anti-trust lawsuit against NASCAR and its CEO Jim France, have abated.

The two teams took the sanctioning body to court after refusing to sign up to a renewal of its charter system, alleging that with the charters NASCAR had a monopoly to force economic terms on teams so that they could barely afford to compete in the sport.

ABOVE Tyler Reddick, leading driver in the 23XI Racing team, will be competing in 2025 after reaching the NASCAR Cup Series final four this season

Both teams filed a preliminary injunction seeking to retain their charters while the suit is decided, which their legal team suggested could take two years. Both could compete without charters as 'Open' teams, which do not guarantee starting positions in races and pay significantly less in prize money, but NASCAR's Open contract included a clause releasing the sanctioning body from any anti-trust claims.

The injunction was denied on November 8, the judge in the case saying that the two teams could not show immediate irreparable harm to their business, only speculative harm. However, he indicated that he saw merits in the case and added that the teams could file the injunction motion again should the facts involved change.

The teams announced their attention to appeal but speaking to the media at the final round of the 2024 Cup Series last month, Denny Hamlin, co-owner of 23XI Racing and a leading Cup Series driver, suggested that his team competing in 2025 was "to be determined".

A week later, however, it was revealed that both teams plan to field expanded three-car squads in the 2025 Cup Series while continuing to pursue their lawsuit, following the receipt of new Open paperwork that omitted the contentious anti-trust clause.

Gen 3 car to boost NASCAR expansion in Europe

AMERICA'S leading race category plans to increase its presence in Europe with an expansion of the Whelen Euro Series under the new name of the NASCAR Euro Series.

The championship, founded by French rally driver Jérôme Galpin in 2008, became one of NASCAR's four officially-sanctioned international categories in 2012 and the only one outside the Americas.

Now a strategic plan to develop awareness in Europe will see NASCAR taking a more prominent role in the Euro Series, aligning it with the national championships that form the ladder to the top-level Cup series in America and helping Euro Series drivers progress their career in the US.

As part of the expansion the NASCAR Euro Series will introduce technical upgrades to its bespoke race car in 2025, dubbing the programme Gen 3. A test car raced during the 2024 championships and last month the first upgrade, a five-speed sequential transmission, was unveiled. Manufactured by Samsonas in Lithuania, it will replace the current four-speed H-pattern gearbox.

Galpin described the new agreement as fully dedicated to bringing NASCAR to the summit of racing in Europe. "We definitely want to deliver more to our fans, our drivers, our teams, our partners and bring new ones in to discover the unique competition and atmosphere of NASCAR racing at some of the best European racetracks," he said.

Chad Seigler, NASCAR's Vice President & Chief International Officer, believes the agreement will mean new opportunities and excitement for participants and partners in the Euro Series. "As we continue to expand internationally, we're excited to strengthen our presence in Europe," he said.

ARE's PRI launch

ARMSTRONG Race Engineering will be showcasing its latest dry sump technology at PRI this month – the Spintric Air/Oil Separator.

Its Remote spin on oil filter adapter features built in adjustable oil pressure. The billet aerospace alloy 4-axis CNC-machined units accept a common non bypassing spin on filter, and all common AN O-ring fittings, -8 to -16.

The units can also allow the bypassed pressurized oil to have only been pumped one time rather than re-circulated inside the oil pump in the case of wet sump engines. Bypassed oil is returned to the dry sump tank, or wet sump oil pan.

The company also has an optional oil pressure fitting built in for ease of hook up. Each adapter comes with high-, medium- and low-pressure springs.

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MAGIC MOLECULE? MAGIC BULLET? MAGIC EVENT!

Mark Skewis offers a glimpse behind the scenes at the 20th anniversary running of the World Motorsport Symposium

THE secret to the World Motorsport Symposium's success is the fact that I can't tell you about it!

The event's Chatham House rules ensure that some of the industry's key players can come together to share their experiences, challenges, fears and solutions in a safe space. The WMS is not about the sales pitches you find on the annual show 'circus': not even the heaviest of hitters come away without having learnt something new.

This year's event, which marked 20 years since the inaugural symposium, was held at the Royal Automobile Club, in Pall Mall, London. If the venue's luxurious settings screamed 'tradition', the challenges that were uppermost in most attendees' minds are relatively new imposters: climate crisis and the energy transition, factors that are shaping the direction of every OEM, supplier and sanctioning body in the sport.

The biggest takeaway from the 2023 WMS had arguably been the impact of Artificial Intelligence/Machine Learning. The opening presentations of this year's event – delivered by Neil Ashton, WW Tech Leader for CAE at Amazon Web Services (AWS) and Amir Vaziri, Head of Customer Development at PhysicsX – quickly reminded us why it has become such a hot topic.

The use of AI, with its overtaking predictions, is already shaping the way that we broadcast races, but how long before the technology is actually determining the story itself? After all, real-time predictions remain something of a Holy Grail for race engineers.

The sessions noted that the cost of training the ML models is extremely high, so "perhaps that ChatGPT moment is still some way off?" They also posed the question of how much the models actually require the hard physics to do their work – the industry is still in its infancy but perhaps, like a toddler, AI can learn intuitively...

The role of sustainable fuels and hydrogen also featured prominently on day one, with Steve Sapsford, Managing Director, SCE, offering an expert introduction to sustainable fuels, while Shell's Dr Valeria Loreti explained how IndyCar had used rhem to slash its greenhouse gas emissions by 60 per cent.

More than ever before, thus year's event truly was a *World* Motorsport Symposium, with North American giants NASCAR and IndyCar both sending delegations. It was the first time the latter has attended, with Mark Sibla, Chief of Staff, IndyCar, ▶

ABOVE LEFT A stellar line-up for the presentations and panel sessions debated the issues that are shaping the direction of the sport and its suppliers alike

ABOVE The Race Tech awards were collected by (from left to right): Barrie Colvin, Technical Director, Ru-Bix Advanced Materials; Pascal Vasselon, Vice President, Strategic Motorsport Development, Toyota GAZOO Racing; Soheila Kimberley, Kimberley Media Group Publishing Director; Giuseppe Pesce, Director of Aerodynamics, McLaren Racing; and Michael Muerlebach, Director, Bosch Motorsport

RIGHT Having just delivered the 2026 F1 aero rules, Jason Somerville, the FIA's Head of Aerodynamics, treated us to a 'Here's what you could have won…' moment, revealing some of the concepts that were considered but ultimately discarded

and Darren Sansum, Managing Director of Engine Development, sharing a 'Fireside Chat' with WMS co-chairman Pat Symonds. This format also marked a departure for the event, which worked well. In the end, the fire wasn't needed.

IndyCar, of course, has completed its transition to hybrid power in the last few months, while NASCAR provoked its fanbase with its controversial EV concept, clothed in CUV/SUV bodywork. Eric Jacuzzi, Vice President, Vehicle Performance, NASCAR, gave the audience an insight into the aerodynamics challenges posed by the project and the lessons learned.

The great thing about all our trans-Atlantic visitors is that they didn't just wing in and out: they contributed immensely throughout the entirety of the event.

Jason Somerville, the FIA's Head of Aerodynamics, had been working flat-out in the weeks leading up to the event as his team concluded the 2026 F1 aero regs. For me, his presentation captured the spirit of the WMS, underlining why it remains so special. Instead of merely running through the 2026 car that all the top tech figures are familiar with, he treated us to a tour of some of the 'outtakes', designs considered but then discarded. Some of them were pretty radical...

The "magic molecule", hydrogen, is increasingly a player in motorsport's response to the energy transition and was well represented across both days.

Pascal Vasselon, Vice President, Strategic Motorsport Development, Toyota GAZOO Racing, brought us up to speed with the Japanese manufacturer's ▶

LEFT America's premier single-seater race series, IndyCar, attended for the first time. Here Darren Sansum, Managing Director of Engine Development, and Mark Sibla, Chief of Staff, IndyCar, share a chat with WMS co-chairman Pat Symonds. Darren and Pat inadvertently discovered that they share near-tribal soccer rivalries, which is presumably why Mark is between the two…

RIGHT Dr Eric Jacuzzi, Vice President, Vehicle Performance at NASCAR, revealed some of the toughest challenges that shaped the aero development of NASCAR's EV prototype

BELOW RIGHT The Royal Automobile Club was an apt setting for the discussion sessions

BOTTOM RIGHT Should governments introduce a sliding scale for fuel duty, according to sustainability? It was just one of many points raised in the sustainable fuels panel session. From left to right: Steve Sapsford (SCE); Dr Valeria Loreti (Shell); Thomas Fritsch (TotalEnergies); Ian Smith (Motorsport UK); and Darren Sansum (IndyCar)

BELOW A drinks reception preceded the awards dinner

LEFT F1, IndyCar and NASCAR share a table at the awards evening

development of a liquid hydrogen-powered Corolla, while Bernard Niclot, the ACO's Mission H24 Innovation Director, and ACO Competition Director Thierry Bouvet looked ahead to the technology's introduction at the world's greatest endurance race.

Day two featured further contributions from Pierre-Jean Tardy, Chief Engineer Hydrogen, Alpine Racing for clean mobility, and Serge Grisin, Motorsport Director, Symbio Motorsport, discussing H2 combustion and fuel cells respectively. The two technologies could soon be rivals on the racetrack, but at WMS24 there was at least consensus across the divide: their introduction is not about decarbonizing motorsport, so much as facilitating the development of a hydrogen ecosystem that can benefit wider society.

Thriving in Turbulence

David Salters, the President of Honda Racing Corporation, is a long-time supporter of the WMS. He is a highly-skilled engineer who, like many in the room, almost had management thrust upon him, so it was fascinating to hear his take on management lessons from motorsport. "Technology is critical but the most important thing we have is people," he reasoned.

Salters reported that the biggest upshot of the electrification of IndyCar, as in IMSA, was the influx of young engineers attracted by the challenge of working with the new software/control systems.

Dr Ulrich Baretzky, co-chair of the WMS, remarked during the awards evening that, after 20 years, the event had come of age but that it was never too old to

BELOW The heart of the WMS: Soheila Kimberley, flanked by her three musketeers, Ulrich Baretzky, Pat Symonds and John Iley. Together, they make the event happen

stop leaning. That opinion was still ringing in many people's heads the next morning when Charlotte Phelps, Chair of the Women in Motorsport Committee for Motorsport UK, made an impassioned plea not just to improve STEM opportunities to tempt females into motorsport – but for us to listen to them once they are there. It was a challenging, and welcome, moment that I am sure future events will revisit.

One man whose team includes some of the most respected female engineering talents in motorsport is Multimatic Special Vehicle Operations Executive Vice President, Larry Holt. Always a refreshing presence, he explained how Multimatic had with Ford's blessing turned a racecar back into a truly spectacular road car: the Mustang GTD.

The majority of Multimatic's other cars (although not this one) feature transmissions from Xtrac. The UK company's CEO, Adrian Moore, shone a light on the confusion that has afflicted the entire industry when he shared the breakdown of the transmissions sold (ICE, hybrid and EV) compared to industry predictions.

The symposium concluded with three fascinating presentations on battery technology. Between them, Dave Greenwood (Director for Industrial Engagement, and CEO of the High Value Manufacturing Catapult at WMG), Douglas Campling (Head of Motorsport, Fortescue Zero) and Gavin White (COO and co-founder of About:Energy) covered territory ranging from electric motorcycles, to fast-charging and the cell characterization of batteries in F1 cars compared to Formula E.

It spoke volumes of the whole event and the standards of the presentations that even now, late into day two, well into 'graveyard shift' territory, still nobody was sneaking out the exit.

"Feedback was that it was the best event we've ever staged," said Kimberley Media Publishing Director Soheila Kimberley. "I'd like to thank Ulrich (Baretzky), Pat (Symonds) and John (Iley), without whose tireless work there wouldn't even be an event, plus the sponsors and my entire team. They all deserve congratulations and a good night's sleep! But what I can't stress enough is that everybody who attended played such a huge role. David Salters was so right: the technology is crucial, but ultimately it's all about the people. And the people were fantastic."

ABOVE Ulrich Baretzky and Soheila Kimberley reflect on 20 years of the WMS

BELOW Charlotte Phelps offered a challenging call-to-arms for women in motorsport

BOTTOM The cabinet members debate the role of hydrogen in motorsport and the creation of a wider ecosystem for the technology in society

McLaren emerges into light at end of the tunnel

Tony Dodgins examines how the Woking squad's "rudderless" ship was guided back to glory

THE quest for McLaren's ninth constructors' championship has been a long one, stretching back to 1998!

The team did top the standings in 2007 before being disqualified and fined $100m for its part in F1's 'Spygate' controversy, but a remarkable turnaround in fortunes over the past 18 months sees it on the fringe of a return to the glory days after a quarter-century hiatus.

The man who built the team into an F1 goliath, Ron Dennis, sold his McLaren shares on his 70th birthday in 2017 to Mumtalakat, a Bahraini sovereign wealth fund, and long-term business partner Mansour Ojjeh, in a deal worth £275m.

The man Ojjeh chose to run the company was American Zak Brown, already a successful self-made man with a stellar record on the marketing side of motorsport. Some questioned Brown's technical know-how and whether he might be better-suited to running the business for F1's new owners, Liberty Media.

"McLaren was more appealing because while I love the commercial side, I love the racing more, and you don't get that with the Formula 1 job," Brown explained. "I felt I could do a good job. For me, being in the garage trumped deal-making – having a team shirt on, getting up on the podium. I felt like McLaren had everything that Liberty could offer me, plus the racing, and the racing side is my true passion."

Ojjeh had originally taken a 50% stake in McLaren International back in 1983, in return for financing the TAG Porsche engine for F1's turbo era first time around. He died in 2021, aged 68, and Brown describes him as the greatest human being he's met.

"He was just awesome. Extremely witty, extremely tough, a total racer, completely loyal to his team and his family, just a first-class guy. I wouldn't have joined if it wasn't for Mansour and Sheik Mohammed making me feel so very wanted.

"I first met Mansour when I was doing the sponsorship. I knew him, but not that well. I was always a bit intimidated by his gravitas and seniority. Like I knew my place! Ron ran the day-to-day but you knew Mansour was big and because he was quieter and behind the scenes, that made him all the more intimidating." ▶

RIGHT & BELOW
Zak Brown, Lando Norris and Andrea Stella in the new wind tunnel at the McLaren Technology Centre (MTC), which has played a key role in the team's resurgence with its MCL38

Photos: McLaren Racing

Speaking of intimidating, how did Brown feel walking into McLaren Racing without the kind of technical background that Dennis obviously had? And, at a crisis point in the team's history. In 2017, McLaren had scored just 30 points and was ninth in the constructors' championship. There were 1000-plus staff at a very low ebb.

"It *was* pretty intimidating," he admits. "Worse than I thought it was going to be. The sponsors weren't happy, the employees weren't happy and it was not a good environment. Plus, anytime you've got trouble at board level, it trickles down.

Revolving door

"It was kind of a rudderless ship because you'd had Martin Whitmarsh in, Whitmarsh out; Ron back in, Ron out; Eric Boullier in, Boullier out; Jost Capito in and out and even a bit of overlap. In any organisation, if you have four different bosses in five years, that's not healthy. The biggest thing I needed to do was convince people that I was going to be around a while. Nobody wants to see that the top position is a revolving door.

"I had a good amount of credibility but not for running a team. It took me two or three years to feel I was making strides. There's still a lot I don't know about the technical side but my knowledge today is 500-fold better than it was coming in. I needed to make sure I didn't lose credibility by showing naivety or lack of understanding. I had to lead but avoid any mis-steps."

ABOVE Daniel Ricciardo's win at Monza in 2021 ended a long drought

BELOW The Miami aero upgrade transformed the MCL38 into what has often been the quickest car in the field

Ninth became sixth in 2018, fourth in 2019, and third in 2020. It was fourth again in 2021, but the team scored 275 points and Daniel Ricciardo returned it to the winner's rostrum at Monza for the first time since 2012. That year's car, the MCL35M, was basically carried over from 2020 due to the COVID-19 pandemic but adapted for a change from Renault to Mercedes power, as F1's new ground effect regulations were delayed until 2022 and aero development was restricted. ▶

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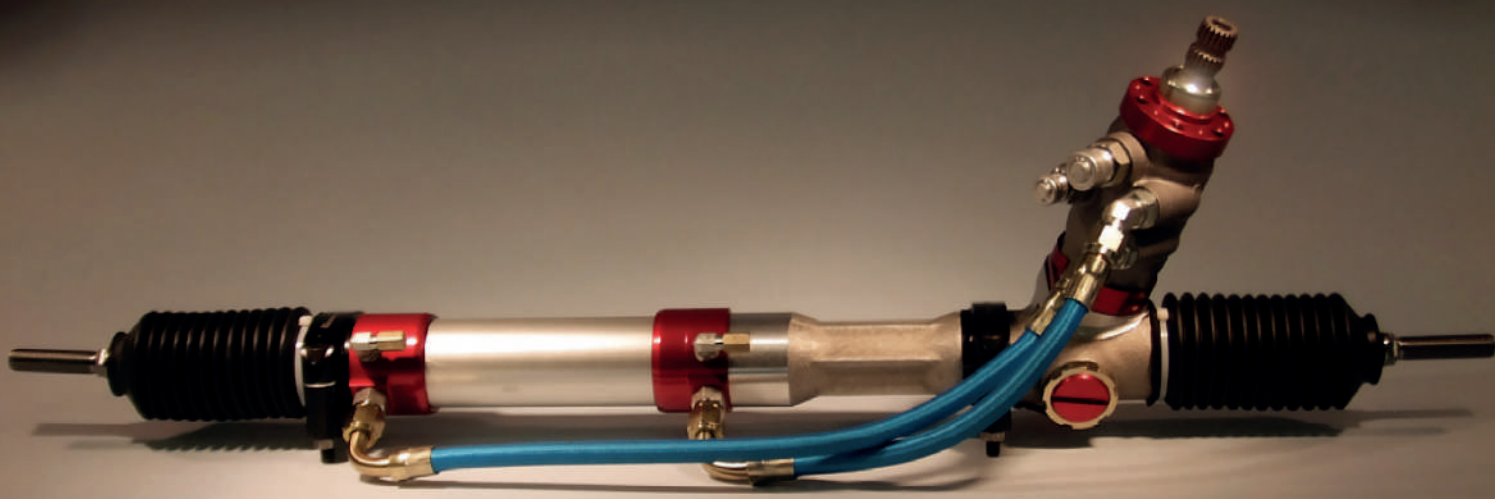

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Although Andreas Seidl had joined from Porsche as team principal in 2019, and James Key signed as technical director in 2019 to replace long-term McLaren man Tim Goss, the '20-21 car was largely the work of a technical team comprising Andrea Stella, aero specialist Peter Prodromou and deputy head of design, Neil Houldey, who joined McLaren back in 2006 after five years with Lola.

After Stella graduated in aerospace engineering from La Sapienza University in Rome and completed a PhD in mechanical engineering, he worked at Ferrari for 15 years, beginning as a data engineer in the Michael Schumacher days.

From the beginning, he developed a stellar, excuse the pun, reputation. Brazilian Luciano Burti, these days a commentator with TV Globo but a Ferrari test driver in the early noughties, said that Stella's grasp of data was so uncanny that it was almost as if he was in the car with you. Moving into race engineering, he looked after Kimi Raikkonen before forging a strong relationship with Fernando Alonso that saw him move to McLaren with the Spaniard in 2015.

The timing, in the early days of F1's new turbo hybrid era and Honda's new engine project, which Ron Dennis tried to speed along before the Japanese were truly ready, was far from ideal for Alonso, but Stella's qualities were rapidly appreciated by McLaren.

But investment in McLaren's infrastructure and facilities was badly needed. The team's Norman Foster-designed Technology Centre was state-of-the-art when built at a cost of £300m and opened in 2004, but that was no longer the case. The wind tunnel in particular was not fit for purpose and had not been used since 2012, when McLaren started to use Toyota's Cologne-based tunnel. The team's simulation, machining and composites facilities were also in need of upgrading.

Heads roll

That did not help Key cope with the demands of F1's new ground effect rules and the team dropped to fifth in the constructors' championship in 2022, behind Alpine, with just a lone podium finish. When upgrades for the '23 car were delayed and the team languished last in the championship after the opening two races of 2023, Key was released. Seidl, too, was on his way, the pair reunited to run the transition from Sauber to Audi's works effort before being replaced there by ex-Ferrari man Mattia Binotto.

Another technical reshuffle under newly-promoted team principal Stella re-energised McLaren and saw the Stella/Prodromou/Houldey triumvirate once more leading the executive technical team. They were further bolstered by what Brown called "an unmissable opportunity" to sign the highly-experienced Rob Marshall, 18 years at Red Bull, in early '24. Houldey, in fact, newly promoted to the role of Technical Director, Engineering and Design, agreed to a deputy role in order that the team could secure Marshall (Red Bull's Chief Engineering Officer) as Chief Designer.

> *"It was worse than I thought it was going to be. The sponsors weren't happy, the employees weren't happy and it was not a good environment"*

"Our turnaround is 100% people-related," Brown states. "Andrea has been awesome and we've had a total change of leadership. The difference between how the team is led now, is night and day."

Brown calls Stella 'The Swan'. "He looks like he's a nice guy cruising above the water but, underneath, he's paddling fast. He's very tough, very professional ▶

BELOW Zak Brown has brought the good times back, ending the revolving door policy that hampered the team's progress

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and very articulate in his delivery. He's not political and has no ego at all. I'm pleasantly surprised not just by what he's brought to the table, but how quickly it's had the impact it has."

Which is something of an understatement. At the opening race of the 2023 season in Bahrain, Lando Norris made six pit stops with a pneumatic pressure leak and finished last of the 17 cars running, while new signing Oscar Piastri was an early-race retirement after qualifying 19th. Competing with the likes of Max Verstappen and Red Bull looked nothing more than a pipe dream. And yet, by season's end, that's what McLaren was doing.

Well before McLaren's recommissioned on-site wind tunnel was switched on in October '23, the normally conservative Stella was already confident that upgrades brought to the car at the Austrian GP last year, round nine, would be a significant improvement. And he was right. With a sixth place Norris's best result up to that point, Lando was fourth at Red Bull Ring and then followed up with consecutive second places at Silverstone and Hungaroring. Lewis Hamilton, who battled with the McLaren in the British GP, called it a rocket ship.

ABOVE Not since the dominance of the McLaren-Mercedes MP4/13 in 1998 had the team won the Formula One Constructors' World Championship

The technical team suddenly had a better understanding of what its MCL60 was doing, with heavy revisions to the floor, barge boards, sidepods and front wing. They helped both the car's porpoising problems and high-speed instability as well as improving tyre degradation.

Huge transformation

It was a huge transformation. Before Austria the team had scored just 17 points in eight races. In the remaining 14, it scored 285! Red Bull was in a league of its own in the most dominant season in F1 history. Behind it though, second-placed Mercedes averaged 18.6 points per race, compared to third-placed ▶

BELOW The upgrades introduced for last year's Austrian GP weekend set the team on an upward trajectory

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Ferrari's 18.4 and fourth-placed McLaren's 13.7. But, from the point at which the MCL60 got its Austrian upgrade, the team's strike rate was 20.3 points per race, beaten only by Red Bull. It left Brown optimistic that his team could challenge for the championship in 2024 – and that optimism was not misplaced.

Although F1 development is continuous, major upgrade cycles differ from team to team depending upon their priorities. Red Bull, for example, was so dominant in 2023 that it was able to spend more time working on this year's RB20 and started the new season looking as if it was set to continue sweeping all before it. Behind it, both Ferrari and Mercedes seemed to have made a bigger between-season step than McLaren. As far as Norris's hopes of challenging for the drivers' championship were concerned, this was when it got away from him as Verstappen won seven of the first 10 races.

It was not until round six of the '24 season in Miami that McLaren's major upgrade turned it into the class of the field and allowed Norris to win his first grand prix. Thereafter the MCL38 contended for wins everywhere, Norris winning in Holland and Singapore with Oscar Piastri also taking his first grand prix victory in Hungary and also winning in Azerbaijan in September, which is when McLaren actually overhauled Red Bull to take the lead in the constructors' championship.

The significant Miami upgrade included an all-new floor, further re-sited radiators, new sidepods and radiator inlet bodywork, strongly improving the underfloor performance. The car stayed largely the same until a new floor appeared in Mexico although a two-part upgrade introduced across the Dutch and Italian GP weekends in late August/early September brought revised floor edges and sidepod shape, with Norris scoring a dominant win in Zandvoort.

Impressed

What has particularly impressed Marshall is how everything that McLaren has brought to the car has worked, co-ordinating perfectly with the wind tunnel and simulations, which has certainly not been the case across the grid as a whole. All three of McLaren's main rivals – Red Bull, Ferrari and Mercedes – have brought things to the track that have either been removed or have needed further validation.

Marshall has also been influential in McLaren

BELOW Following Red Bull's most dominant season in F1 history, gamblers would have got good odds against McLaren arriving in Las Vegas leading this year's constructors' title

> *McLaren is making progress with aero-elasticity, something Red Bull has been renowned for"*

making progress with aero-elasticity, something Red Bull has been renowned for in recent seasons. A new low-downforce rear wing used in Spa, Monza and Baku achieved a 'mini-DRS' effect through flexing at the outboard ends when the speed reached a certain point and was important in Piastri being able to defend Charles Leclerc down Baku's long straight having passed the Ferrari immediately after the pit stops. It was slightly controversial and while the FIA admitted that it broke no regulation, the governing body did tell the team to ensure it did not flex as much in future.

New rear wings – high downforce at Zandvoort and medium downforce at Interlagos – were also introduced, which did much to eliminate a deficit to Red Bull in how much speed was gained through DRS. Stella admits that McLaren had not focused enough on aero elasticity before and was able to do so because of efficiencies necessitated by F1's cost cap.

ABOVE The investment in the new wind tunnel is paying off. Above, the wind tunnel project team; below, the demolition process of the original tunnel

The strong correlation between wind tunnel and track has also been aided by McLaren's new tunnel, the problem with the older one being that its working section was not big enough. As F1 cars have grown, wind tunnels have needed to as well. The original McLaren tunnel was designed to operate with a 50% scale model but in order to improve the reliability of test results, a switch to a 60% scale model was needed. That, however, was on the verge of being too big for the wind tunnel. If part of the model is too close to the walls, it impacts airflow and leads to incorrect data.

While the Cologne tunnel has been important to McLaren, there are benefits to bringing aero testing back in-house. Operationally, removing the time and component shipping costs associated with the 388-mile Cologne round trip is a plus, as well as having the full team onsite to support, and will increase McLaren's ability to develop faster.

Thus far, McLaren has also benefited from the FIA's aerodynamic testing restrictions, which dictate a sliding scale of tunnel hours and CFD usage in reverse championship order. McLaren was sixth in the points prior to last year's July-December period, fourth for January-June this year, and still only third ahead of the current July-December period.

So, as well as having a new tunnel, McLaren has also been able to make more use of it than its main rivals, but that changes with success!

Challenging physics

The correlation between wind tunnel and track is so important to prevent teams heading down blind alleys in a cost-cap era, that Ferrari went as far as producing a new floor to run solely on Carlos Sainz's car in the first session of free practice in Las Vegas, purely to validate its tunnel data. And, ahead of a swingeing set of new regulations for 2026, that correlation will only become more important.

"I think it's important to have the latest tunnel technology," Stella says, "because we are dealing with complex aerodynamics and some challenging physics. But I think if we have a competitive car, the praise goes to the aerodynamic team that has been able to achieve such a development success rate."

If there has been any valid criticism of McLaren in 2024 it has sometimes surrounded a lack of operational sharpness. But it is not standing still. Will Courtenay, with 20 years' experience at Red Bull has, like Marshall, made the move to Woking and joins McLaren as Sporting Director. Brown has well and truly chocked shut that revolving door and McLaren's current rosy garden is a combination of empowered existing team talent, strong management and savvy investment. The team looks set for a return to the glory days.

HAVE WE JUST HIT THE SCIENTIFIC JACKPOT?

End-of-life recycling of batteries is a divisive issue for sectors that embraced electrification in the quest to 'go green'. **Olivia Hicks** visits an Indianapolis-based company that claims to have the answer

THE missing piece in motorsport's battery recycling problem sits inside a warehouse in a nondescript strip mall 30 minutes outside of Indianapolis.

Two cylindrical machines stand tall in the centre of the building, that measures smaller than an Olympic swimming pool. One of the 15 staff members has rolled a whiteboard filled with complex equations awkwardly towards one wall, and the racks of supplies are crammed in a way that screams organised chaos. Then the lab appears. Inside its four pristinely sterile walls, roughly the size of a childhood bedroom, is Indiana's best-kept secret.

ReElement Technologies is a new company, born in 2020 as "American Rare Earth" and rebranded two years later as ReElement. The company aims to recycle lithium-ion batteries – the ones you'd find in iPhones, laptops and, most importantly, electric vehicles – and extract what it calls "rare earth elements", also known as mineral ores or virgin ores. Its parent business, American Resources Company, began with ties to the coal industry, hoping to "improve and steward those [natural resource] assets back to their true value."

In July, the company announced it had hit the equivalent of a scientific jackpot: recovering more than 99.5 per cent of the elements necessary to power electric car batteries: lithium, cobalt, manganese and nickel.

As electric vehicle sales surge, ReElement saw an opportunity to get ahead of the inevitable demand for disposing of these batteries. Lithium-ion batteries only hit commercial success 15 years ago, largely due to their

ABOVE ReElement's vision is for motorsport to act as a marketing tool as well as a customer

Porsche AG

10-year lifespan. But while the tech giants buying up Silicon Valley pushed lithium's longevity agenda and the Prius effect grabbed the U.S. by its bootstraps, the end-of-life for these batteries was a hazy, far-off afterthought.

Then the 2020s began and dealing with car battery waste from the 40 million electric vehicles on the road was no longer something on the horizon but an environmental threat at manufacturers' factory doorsteps. Companies were stuck: vehicles labelled as "net zero" needed to have both a production and disposal method just as clean and green as the name suggested. The industry quickly realised that wasn't feasible.

> *"Tech giants buying up Silicon Valley pushed lithium's longevity agenda, but the end-of-life for these batteries was a hazy, far-off afterthought"*

Lithium-ion batteries require a handful of key minerals, the kind ReElement has successfully extracted. Cobalt, manganese and nickel come together to create a cathode, a structure that mixes with lithium and is necessary for the electrode exchange characteristic of any battery. But those minerals aren't found by digging in your backyard. Instead, they call the Congo, South America and Australia home. And there's a limited supply.

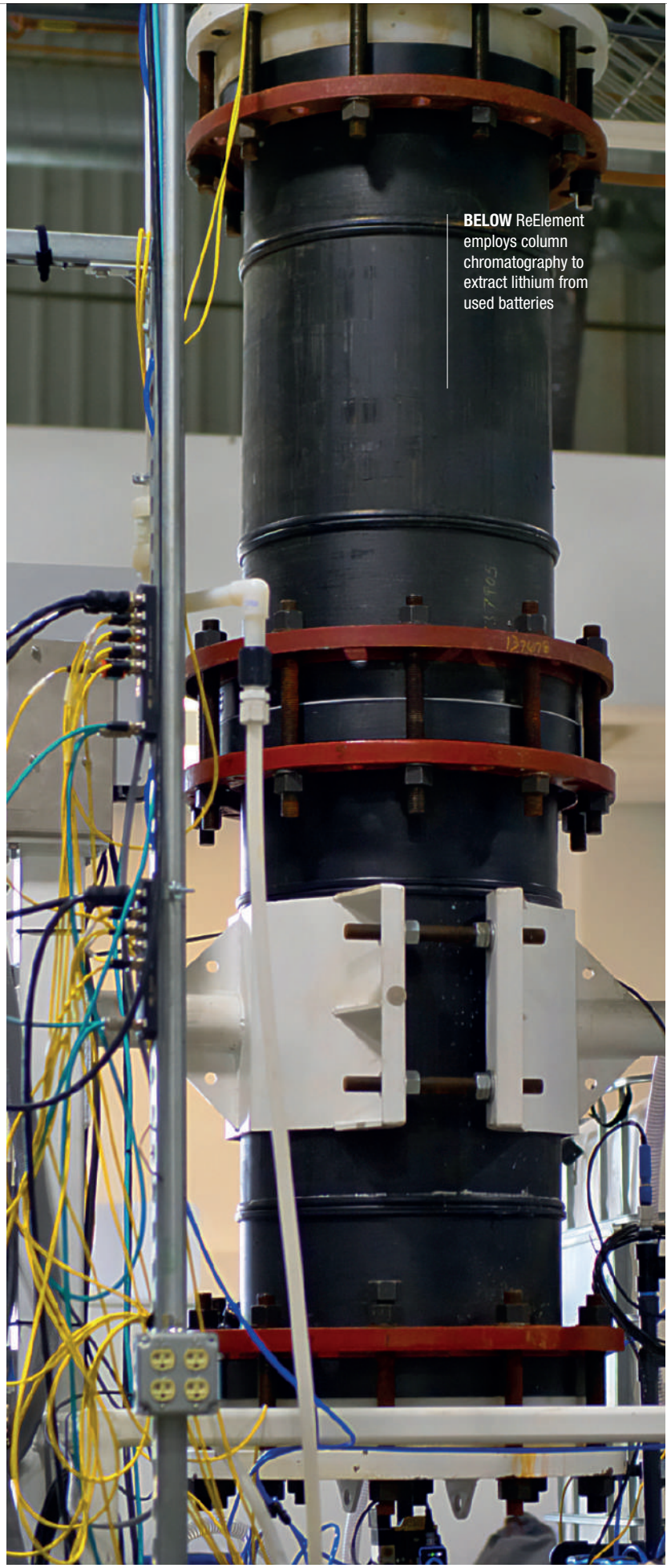
The mining process often disrupts local landscapes and communities. Environmentally, the process has a lengthy disclosure, from soil erosion and biodiversity impact to contamination and pollution. Socially, the Democratic Republic of Congo has faced allegations of human rights abuses against workers – sometimes children – for unsafe working conditions, the uprooting of communities for mining activities and low wages.

Blood diamond

Cobalt, the main mineral extracted from central Africa, is nicknamed "the blood diamond of batteries". The tech boom, allowing electric vehicles to flourish, carries a hefty portion of the blame. In 2019, Apple, Google, Dell, Microsoft and Tesla were named in a U.S. lawsuit over children killed and injured in Congolese cobalt mines.

Global demand for lithium-ion minerals will only surge. According to the Massachusetts Institute of Technology, "As the world transitions from gas-powered to electric vehicles, the demand for these materials will far outpace the supply from recycling, so mining metals such as cobalt will still be necessary."

As the human rights and environmental arguments ▶



BELOW ReElement employs column chromatography to extract lithium from used batteries

Photos: Porsche AG

stack higher alongside demand, companies that can recover elements in lithium-ion batteries are becoming hot commodities. As one of them, ReElement is taking a different approach: enlisting motorsport as both a marketing tool and a customer.

Car batteries rarely enter the sustainability picture of motorsport. Part of the reason is because, in the history of the sport's top series, they're relatively novel.

While the ingenuity of the double diffuser stole the headlines – and the F1 titles – for Brawn GP in 2009, the sport's real technical landmark was the introduction of Kinetic Energy Recovery Systems. It meant that for the first time F1 cars were aligned with their everyday commuter cousins by dint of carrying an onboard battery.

F1's first steps into this new frontier were faltering: the benefit of early KERS systems barely compensated for the extra weight the cars had to carry. Just four teams adopted the system and only McLaren and Ferrari persisted with the technology for the whole campaign.

Not until 2014, when ERS replaced the original system, did the hybrid powertrain truly dethrone aerodynamics from its customary position as the F1 king. Come 2026, Formula 1 will rely on a true hybrid battery: a 50-50 split between electrical power and the ICE will generate around 1,000 horsepower.

While lithium-ion batteries are famous for their durability, racecars' 300-plus kilometre per hour strain on battery power means regular replacements. If a driver exceeds four power unit replacements in Formula 1, he will face a 10-place grid penalty. The piles of used batteries begin to rise taller as the season chugs on.

Extreme E, transitioning to 100 per cent hydrogen power in its rebrand to Extreme H, is confident it has hit the longevity lottery.

"There is no reason to believe that [the battery] won't carry on into season two, season three as well," Mark Grain, Extreme E and H's technical director, says. "We don't anticipate that there's going to be a high level of swap out or anything like that at all. In fact, there should be stability for at least three seasons."

But as Formula 1 and IndyCar attempt to catch up to all-electric series in battery longevity, they have to address their waste streams.

Formula 1 aims to be net-zero by 2030. In the past six years, the sport cut its carbon footprint by 13 per cent. The single-seaters make up a crumb of Formula 1's total environmental impact, but they do serve as a temperature check for the current state and future of the automotive industry, just as IndyCar and Formula E do. The same sport that pioneered regenerative braking and the rearview mirror, racing is now considering what example it can set for automotive manufacturers. On top of switching to increased hybrid power in 2026 and using sustainable fuels, Formula 1 is attempting to tackle logistics, its biggest emitter. This involves carrying all the moving parts necessary, including batteries, to-and-fro circuits. In 2023, Formula 1 introduced a fleet of bio-fuelled trucks to transport equipment across the European race season. The fuel switch cut related emissions by 83 per cent.

Viable solution

Formula 1 doesn't dive into the specifics of battery recycling in its annual sustainability report and neither does IndyCar. Formula E does. The all-electric series reported in season eight that 95 per cent of metals were extracted and 60 per cent were recycled through Belgian recycling plant Umicore. By season nine, 90 per cent of all metals and 80 per cent of

ABOVE & RIGHT Neel Jani, a Le Mans winner with Porsche (above) and an experienced Formula E combatant, is a brand ambassador for ReElement

lithium were "repurposed". Season nine battery cells were recycled to create Season 10's battery. As long as batteries operate above 80 per cent of their original capacity, repurposing is possible.

"This demonstrates that battery recycling is a viable solution, hence the dependency on new metals can be significantly reduced," the series' season nine sustainability report read.

Emissions from transporting old batteries back to Formula 1 factories may have been slashed, but what about after that? Once Formula 1 cars leave the track, in one piece or many, it becomes harder to follow each disposal stream. Its status as a non-spec engineering competition makes it even more frustrating. Unlike IndyCar's one-partner-for-everything model, Formula 1 teams contract with unique suppliers and recyclers.

Saft is able to help decipher part of the battery waste stream process. Supplying half of the grid with batteries, the company claims that each year it uses more recycled materials than the last. Saft extracts up to 95 per cent of metals and the company must recycle 75 per cent of a battery to meet current EU regulations.

"Saft operates a network of over 30 bring back points worldwide," it says. "[Our factory in] Oskarshamn reclaims the nickel, cobalt and cadmium for reuse on-site with the other metals it reclaims such as steel, copper and plastic containers sent to third parties for recycling."

Recycling is a positive buzzword. It conjures up images of smiling good-doers reusing plastic water bottles or not even drinking out of them in the first place. Around the time the term "reduce, reuse, recycle" swept America in the 70s, a blindingly bright future free from dichloro-diphenyl-trichloroethane (DDT), inner-city lead poisoning and murky water seemed to lie ahead. Everyone would join hands and skip and sing the song of world peace.

But, what U.S. regulators failed to mention to avid recyclers is that after they throw their cardboard boxes in the recycling bin, there was no saying where recyclables would end up or which recycling process was actually sustainable. More often than not the answer was the landfill. The small percentage that does arrive at a commercial recycling centre often goes through an unsustainable process to make it reusable.

Lithium-ion batteries often meet a similar fate. The amount of lithium batteries recycled varies, depending on who you ask. Just five years ago, less than five per cent of lithium batteries were recycled, the International Institute for Sustainable Development found. In 2023, Business Insider reported that the number was around 50 per cent.

> *"Cobalt, the main mineral extracted from central Africa, is nicknamed 'the blood diamond of batteries'"*

Turning the tide

But governments are attempting to change that number.

The U.S. poured $150 million into funding lithium-ion recycling through the "Battery and Critical Mineral Recycling Act." The bill, passed in 2020, defined a "battery" as something "rechargeable and electrochemical that included lithium ion and other chemistries." By passing the bill into effect, congress allowed for the Secretary of Energy to award multi-year grants for research, development and implementation of battery recycling technology. In the bill's fine print, a company or organisation must promote collaboration among vehicle battery manufacturers to be eligible.

That same year, the European Union labelled lithium as a "critical raw material" and, in 2023, passed the Batteries Regulation Law. The new act aims to ensure lithium-ion batteries are reused, recycled and, principally, collected in the first place.

The influx of funding and restrictions bridging the two continents across the Atlantic is part of a strategy to cut down U.S. and European dependence on China. The nation dominates the international electric vehicle market not only in production and sales but also in disposal. China processes and produces nearly half of the globe's mineral ores used in batteries and, at the end of their life, those batteries are returned to the country where bags of black mass, or shredded battery materials resembling dark soil, are further processed. Exporting battery waste to Asia is a cheap and efficient solution, the equivalent of the West wiping its hands of a problem. ▶

But, as with plastic, not all recycling methods are equal.

"There's not a lot of clear understanding about what the different stages are," says Linda Gaines, an environmental scientist and transportation system analyst at Argonne National Laboratory (the same lab that created usable nuclear power). "There are a lot of us recyclers, for instance, who just basically grind up batteries and then sell the powder reactance and they call themselves recyclers, but that material then needs to be further processed to be usable, pure enough and appropriate chemically to put back into new batteries."

Companies like Li-Cycle shred batteries into black mass and then sell one metric ton-sized bags for about £2,715 to companies that recycle it further, like ReElement. For every ton of batteries recycled, Li-Cycle says it will avoid five tons of CO2 emissions that would have come from mining new metals.

American and European companies now have an incentive to hold onto black mass and process it themselves. Sustainability is far from the major motivator. The lithium battery market is expected to reach £150 billion in value in less than 10 years. Nickel and cobalt remain the most profitable. In a world governed by cash, a recycled product is only as good as its profitability.

Shifting operations is easier said than done, though. Lithium-ion batteries are notoriously difficult to recycle and not built with recycling in mind in the first place, with lithium remaining the major head-scratcher due to both its health impacts and low recoverability. The resource is less hazardous than petrol-fuelled cars' lead-acid batteries but lacks the nearly 100 per cent recycling rate that lead batteries enjoy and can burst into flames at any given moment.

Most recyclers use a smelting process to recycle and extract lithium-ion minerals, but only nickel and cobalt can be recovered through the high-heat method. Although smelting is technically labelled as recycling, it poses its own pollution problem – failing to meet the green image the public may choose to believe.

ReElement is convinced the sanitary and streamlined solution to a billion-dollar hurdle is tucked inside its suburban warehouse.

Chromatography pioneer

The science behind ReElement Technologies started in a lab on the Indiana plains. Linda Wang, a chemical engineering professor and researcher at Purdue University, was the first person to use the chromatography method, common in the pharmaceutical, drug testing, oil and gas and food and beverage industries. One of her students, Yi Ding, went on to become the director of research and development for ReElement, helping to patent the technology.

"The former president of the Purdue Research Foundation said to me that this is without a doubt the most important technology that Purdue has ever produced," David Sauve, ReElement's chief marketing officer, says. "The implications of it are endless because regardless of how far electrification goes, you're still going to need some type of solution for the existing products out there. Even gas-powered cars still have a tremendous amount of battery ▶

Red Bull Content Pool

BELOW Formula 1 teams sign deals with unique suppliers and recyclers for their batteries. Saft, which supplies half of the grid, says it uses more recycled materials with each passing season

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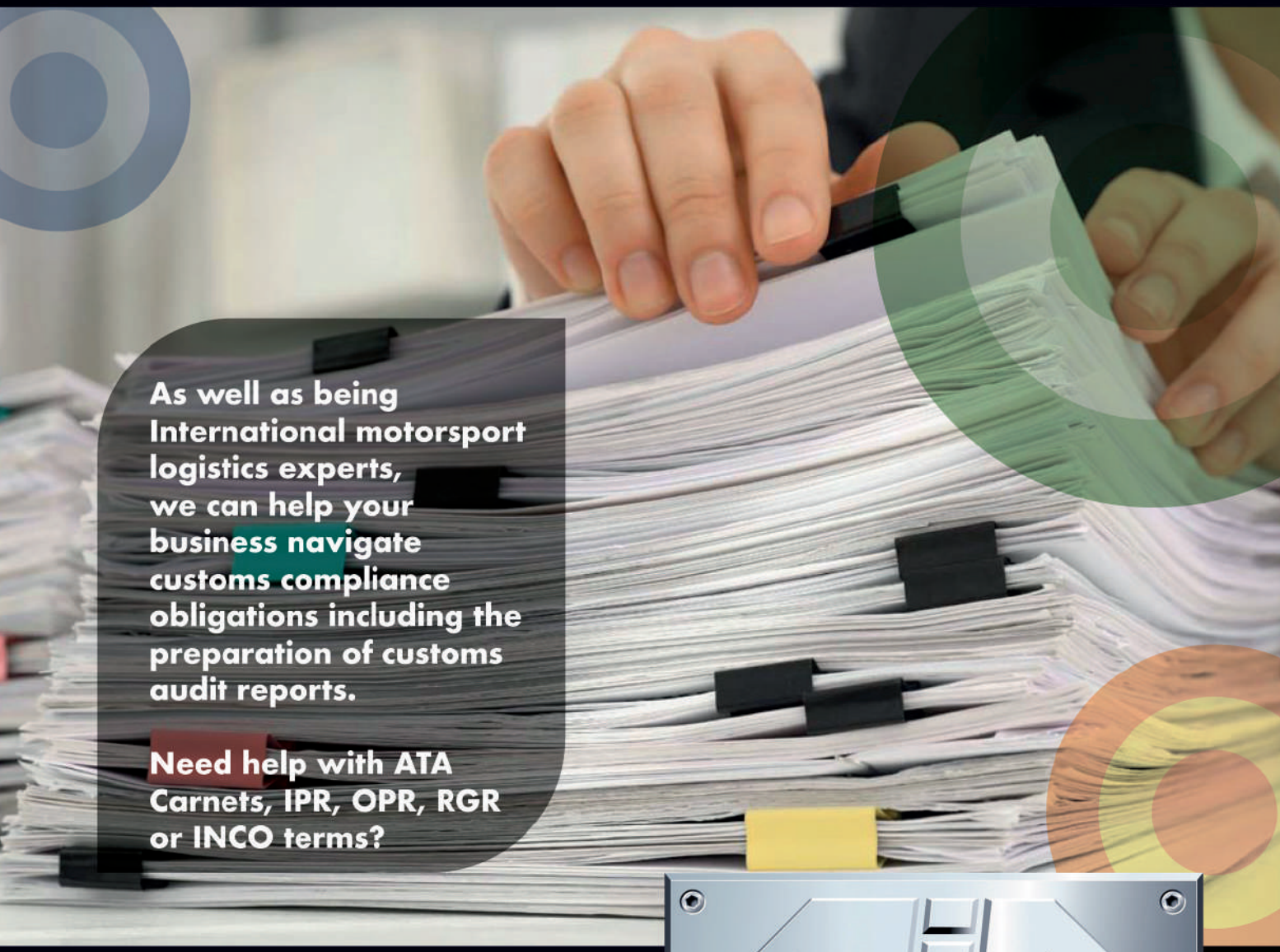

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ABOVE Formula E is one of the few race series to dive into the specifics of battery recycling

material and rare earth elements. So we are not necessarily tethered to the highs and the lows of electrification or EVs."

Chromatography is the separation of a mixture into its initial ingredients via a large column. Unlike the smelting process' loss of lithium, chromatography is one of the few options that extracts it. The secret, just as in racing, is all about pace.

"Let's say you have a very long racetrack that a lot of cars will be running," Ding explains. "There's a group of cars we want to separate and half of the cars have one type of tyre, and then the other half of the cars have a different type of tyre. And those tyres interact differently with the racing track, so that will determine how fast they can run. Let's say one tyre grabs onto the ground very tight, so the car will move slower than the rest. And if we have them all start at the starting line at the same time, then you can imagine that those cars with two different tyres will move at different speeds. That's how we separate this group of cars based on their speed."

That's exactly what's happening inside the columns.

"We're separating lithium from this battery that has lithium, nickel and cobalt," Ding says. "The resin in the column that we choose will lead lithium around faster, way faster than nickel and cobalt. If we pour them into the column at the same time and let it run, lithium will come out first because it runs faster and nickel and cobalt will come out later because they run slower."

Because the speed disparity is so large, there's a clean break between the three elements. "Then we can produce lithium as a high-purity product," Ding says.

The company uses a standard off-the-shelf resin product, the same that's in the sugar or wastewater treatment industries. Comparing the process to industrial standards for battery recycling, Ding argues that chromatography is a more sustainable option than solvent extraction, another popular method to separate the metals and successfully extract lithium.

> ***"Sustainability is far from the major motivator. The lithium battery market is expected to reach £150 billion in value in less than 10 years"***

Argonne National Laboratory uses solvent extraction, also known as hydrometallurgy.

"From our standpoint, smelting loses too many organic materials," Gaines says. "Instead of just throwing stuff into a furnace, you chop up the battery into little shreds. The cathode material is recovered as a powder and that powder is then put into strong acid and all the compounds dissolve. And so you've got ions floating around in the soup and you can precipitate things out and use solvent extraction."

However, Gaines recognizes that solvent extraction may not make the most sense environmentally or in terms of energy.

"Knowing a little bit about chromatography from a chemistry background, it sounds to me like that would make a lot more sense than just throwing everything into a big vat of acid," Gaines concedes. "Sounds like it's a lot cleaner and it should be environmentally and energetically preferable to hydrometallurgy."

As a one-of-its-kind approach, chromatography lacks significant critiques or recognition currently. Gaines notes that "a detailed process analysis" is necessary to compare it to other recycling methods.

Ding's work is centred around exactly that.

"In our column chromatography, the separation would happen on the interface between the resin and the solution," Ding says. "In the solvent extraction process, the separation would happen between the interface of the aqueous phase and the organic solvent phase."

Surface area

In order to speed up the separation in solvent extraction, chemists typically add oil and whisk the solution. The separation of metal ions happens on the surface of those oil drops that naturally won't dissolve in water. The result is low surface area, Ding says. In chromatography, the area used is two to three orders of magnitude higher. In one gram of the resin inside the columns, hundreds of square metres of surface area lie waiting for that separation to happen.

"Instead of using hundreds of mixtures of cellular units, we only need one column to achieve the same purity and the same yield of the product," Ding says. But with "less chemical consumption, less waste, ▶

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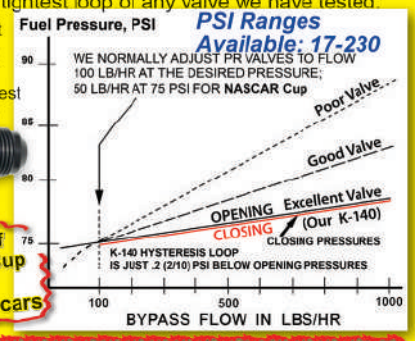

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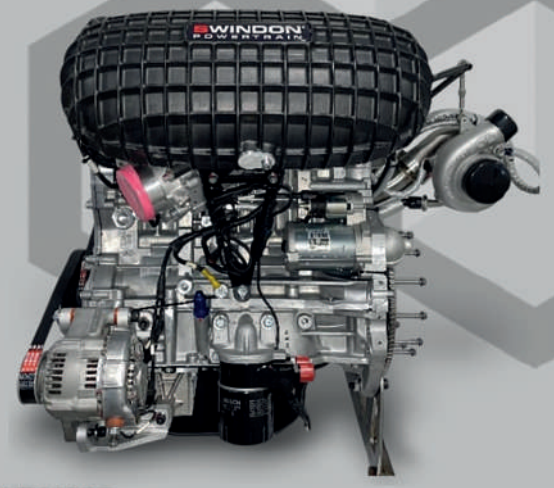

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discharge and also much less footprint."

Ding is looking even further forward to reusing the water, chemical and salt byproducts "so that we don't have to buy as much fresh chemicals. Instead [we] turn the waste into resources."

ReElement's setting, tucked near a gymnastics gym and a handful of American fast-food chains, is less of a shock to the system when its "clean and green" argument is unearthed.

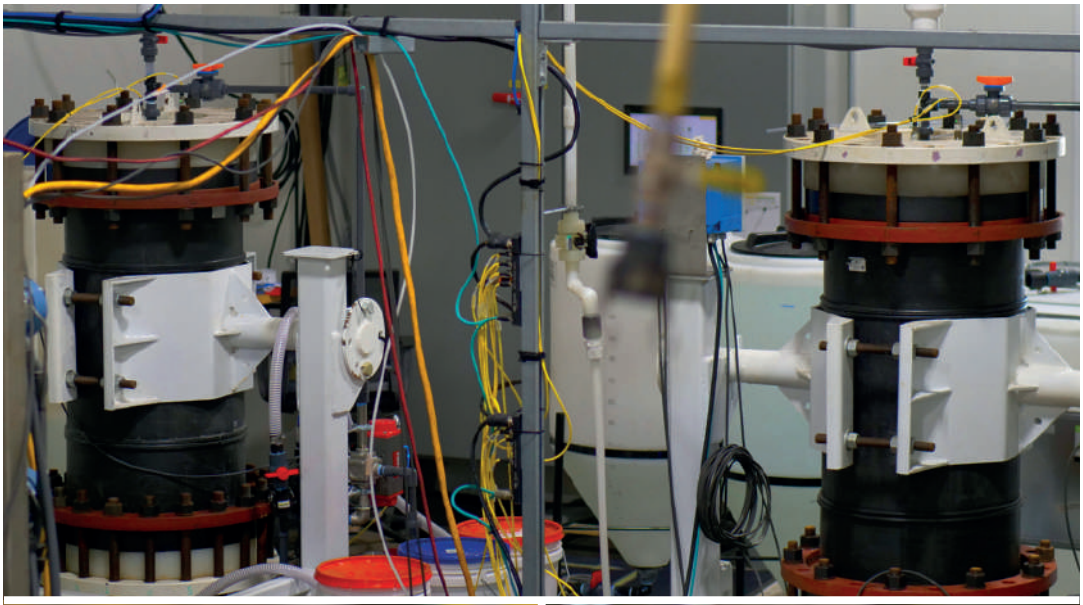
"Look, we can do it here," Sauve says. "Two doors down is a children's gymnasium and then a church. In China, you need a space in the middle of the desert."

Purdue has recently handed over two patents to ReElement: one to treat waste products and recycle black mass, and the other to treat mineral ores. The company aims to treat mineral ores onsite in Africa.

"That now expands our scope to everything from recycled materials to mined ores," Sauve says. "One of the selling points, especially with our developments in Africa, is we can basically load these columns, as many as we need or as few as we need, into a shipping container, ship it over to a mine site in Africa and set it up right at the mine site. So as minerals are coming away from the mine they're being put through our process and refined locally on site. The idea is that it will hopefully spark regional economic activity, being the midstream refining solution. It's either something innovative like this or

RIGHT Many motorsport series are touchy about the final destination of the black mass created when their batteries are disposed of

BELOW Just a single gram of resin inside the column potentially opens up hundreds of square metres of surface area for the separation process



you go to China and do it at a massive scale with great cost to the environment."

Sauve was quick to jump on the motorsport marketing boom that infected the American masses with Formula 1 fever over the past five years. Partnering with FIA World Endurance Championship (WEC), European Le Mans Series and International Motorsports Association (IMSA) driver Neel Jani as the company's brand ambassador, ReElement hopes to begin attracting customers in the racing world.

"There is a way for motorsport teams from IndyCar to F1 to make a little bit of revenue off of this process," Sauve says. "So we would take their stuff, process it and [the] material that is sold back into the supply chain market, they will get a portion of that shared revenue."

It's an attractive offer, especially considering the motorsport series that do disclose end-of-life battery processes use smelting or solvent extraction methods. In July, IndyCar debuted a hybrid power system containing a battery that, eventually, will need to be replaced and disposed of. The series' current recycler is Call2Recycle, but the company doesn't disclose on its website which method is used or where black mass ends up: further processed in-house or shipped elsewhere. The company, along with Saft, did not respond to requests for comment.

Staring at the two columns, attempting to understand the scientific magic trick going on inside them, less than 24 hours after Josef Newgarden crossed the finish line at the Indianapolis 500 felt ironic – and too good to be true. Didn't the high-ups at IndyCar know what they had waiting in their backyard?

Too good to be true?

Among the lofty near-100 per cent recovery claims and zero hazardous byproduct declarations, there's a glaring hole. If this company's technology is the undiscovered recycling solution that will allow U.S. companies to bask in their sovereign profit – untouched by China – why is the sidewalk outside ReElement's headquarters empty? Why aren't CEOs, motorsport magnates, senators and Elon Musk himself shoving past each other to taste a slice of the patented, locked-down chemical recipe the start-up is baking? There should be a line of suitors stretching the 48.4 kilometres from the suburban strip mall to the Indianapolis Motor Speedway.

But even with the huge demand for battery recycling options, plants using new technology, like direct recycling – a process similar to chromatography with promises of safe and high ion recovery – have trouble gaining funding and opening their factory lines. The U.S. Department of Energy is also particular. While ReElement separates all the cathode minerals, Gaines says the government agency is most interested in processes that actually keep the chemical compound intact.

> *"Two doors down is a children's gymnasium and then a church. In China, you need a space in the middle of the desert"*

While companies like ReElement continue to push the boundaries of science, lithium-ion demand will only grow: by 2030, electric vehicles are expected to make up over 60 per cent of vehicles sold globally. And they'll need to be powered by something, whether found in the ground in the Congo or recycled in a warehouse in the Midwest.

For the majority of the globe, the business of battery recycling may be boring, bordering on sleep-inducing.

For Ding, it's not just necessary for the future of the automotive and racing industries but a bit sentimental: "You create something that's beautiful out of chaos." RT

Winner of the Don Burgoon Most Innovative New Motorsport Product of the Year Award

BREAKING BARRIERS

Bosch Motorsport used its expertise in braking technology and vehicle control to develop a solution for braking with hand pedals instead of foot pedals. **Chris Pickering** talks to its creators

ROBERT Wickens was on the crest of a wave in 2018. He'd marked himself out as one to watch in IndyCar, clocking up four podiums in his first full-time season. Prior to that, he'd won titles in Formula BMW and Formula Renault 3.5, worked as a Formula 1 test driver and raced for six seasons in the DTM. He was proving to be one of the most versatile young drivers of his generation.

But things were about to take a darker turn.

Wickens was challenging for third in the ABC Supply 500 at Pocono Raceway when he touched wheels with Ryan Hunter-Reay coming out of Turn 2. Wickens' car was sent spinning into the catch fence, the resulting impact leading to fractures in his neck and spine, both legs, both hands, an elbow and four ribs. It was testament to the safety of the Dallara DW12 that he survived, but the accident had left him in a wheelchair.

Wickens was determined to get back into racing. During the COVID pandemic he took up e-sports, competing in the IndyCar iRacing Challenge and the Virtual 24 Hours of Le Mans. Then, in 2021, he had a call from team boss Bryan Herta. Although they'd never worked together, the pair knew each other from the IndyCar paddock and it just so happened that Herta had a Hyundai Veloster N TCR car equipped with hand controls. Would Wickens like to come and have a go, he enquired?

It was a cold, wet day at the Mid-Ohio Sports Car Course, but nothing seemed to dampen the Canadian driver's enthusiasm.

"The rain was so heavy that the team had been out in road cars just to try to clear some of the water," recalls Jordan Krell, senior motorsport engineer at Bosch Motorsport. "The team told him not to push, because he was already half a second faster than anyone else on the test day. He said, 'I'm not, I'm taking it very easy'."

The car that he drove that day had been adapted for Michael Johnson, an accomplished single-seater and touring car driver who'd been paralysed in a motorcycle racing accident when he

> *"The team told him not to push, because he was already half a second faster than anyone else. He said, 'I'm not, I'm taking it easy'"*

BELOW The hand-controlled system's debut was at Indianapolis, the home of so many tech innovations down the years

was just 12 years-old. Like Wickens, he'd been keen to get back into racing, and had started in a kart with hand controls developed by Formula 1 and CART star Alex Zanardi, who had lost both his legs in a racing accident in 2001.

Johnson progressed through the USF2000 and Pro Mazda single-seater championships into sportscar racing, where he made headlines by winning his first professional race. When he came to Bryan Herta Autosport to race the Veloster in the Michelin Pilot Challenge, the team's then technical director David Brown devised a hydraulic system that would amplify the pressure on the hand controls and use that to apply the foot brake. As with all cars in the series, the Hyundai was shared, in this case with South African driver Stephen Simpson.

Wickens' performance at the test day secured an invitation to drive for the team in 2022, initially paired with fellow Canadian Mark Wilkins. As with the car shared by Johnson and Simpson, the non-disabled driver would use the brake pedal as normal.

Wickens made an immediate impact in the Michelin Pilot Challenge, taking a podium finish on his first race at Daytona and scooping two wins that season. He went on to win the championship with new co-driver Harry Gottsacker in 2023. But despite his obvious speed, Wickens felt there was still potential to improve the hand control system, and that's where Bosch Motorsport and Jordan Krell return to the story.

"Robert [Wickens] had heard about the Electronic Brake System that we use in LMDh and we started talking about whether it could be adapted for a car with hand controls," he recalls. "Then, after several discussions and aligning with BHA, we got to work." ▶

All photos: Levitt/LAT Images

Pedal demand

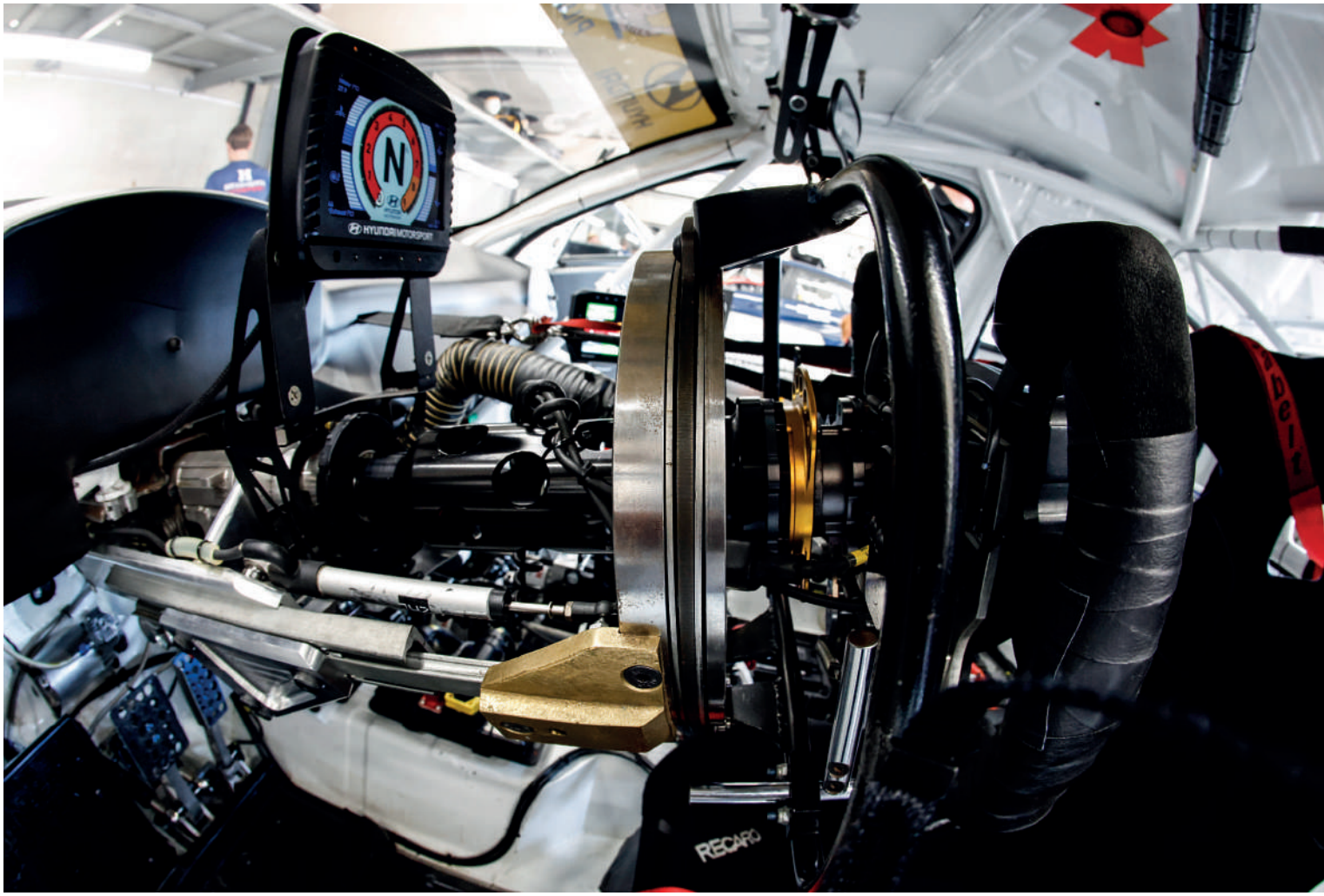
The EBS is effectively a block of electronically controlled valves coupled to a pressurised brake fluid reservoir. Originally intended for blending hydraulic braking with battery regen on electric and hybrid vehicles, it's capable of taking a PWM signal from an external vehicle control module (VCM) and translating that into the required brake line pressure fed into the calipers. In this form, the VCM can calculate how much braking effort will be available from the regen and how much input will be required from the hydraulic system to make that up to the driver's pedal demand.

It functions somewhat differently in Wickens' car. Here, there are two small master cylinders (to provide bias between the front and rear brakes) that are actuated by the hand ring behind the steering wheel. When the ring is pulled back, these send pressure to the input side of the main master cylinders down in the pedal box, mimicking the action of a conventional pedal input. However, the amount of force that a driver can exert with their hands is significantly lower than with their legs, which means that input from the hand controls needs to be amplified to achieve the same effect.

This is where the EBS system comes in. When Gottsacker is driving the car, the system is effectively bypassed; the fluid is still routed through the EBS, but the valves are inactive and it flows straight into the ABS system as normal. When Wickens is driving, the EBS valves amplify the pressure, using pre-pressurised fluid from the accumulator. This brings it up to a comparable level to a conventional ▶

ABOVE A big engineering effort underpinned the successful introduction of the system, ensuring the feel was right and that all safety cases had been considered

BELOW Wickens pulls the brake ring behind the wheel in order to actuate the master cylinders in the footwell



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pedal input. From that point, the fluid is fed into the ABS system and out to the calipers as normal.

A Bosch Motorsport MS6 acts as the controller for the system, using multiple pressure sensors to monitor the pressure coming from the hand master cylinders. A set of look-up tables provide configurable maps that dictate how much additional pressure is applied.

"In the past, they'd used a boost system [that physically amplified the hydraulic pressure]," explains Krell. "The issue there was that it could take 500 milliseconds to reach full pressure. That introduced a lot of latency, so Robert was having to pre-empt his braking, based on where he'd seen the other drivers braking on the previous lap. As a result, it was very difficult to race people hard and pass them."

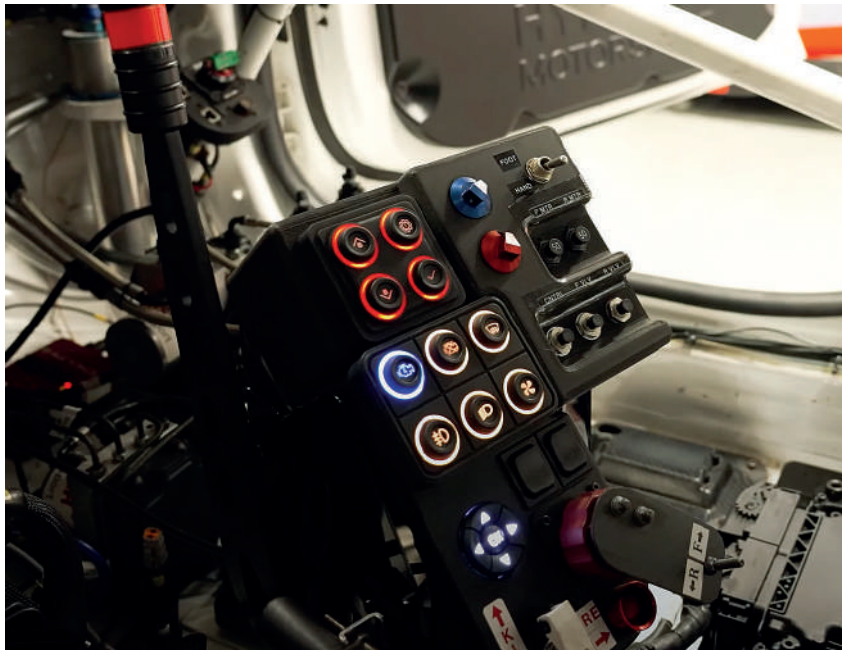
With the new system, the accumulator in the EBS re-pressurises as soon as the driver comes off the brakes, ensuring that the full force is available for the next application. That's slashed the time taken to reach full brake pressure to 40 milliseconds, with partial pressure available instantaneously.

The concept behind the system is relatively straightforward, but as with any safety-critical item, one of the hardest aspects to engineer has been backup and redundancy, Krell explains.

"It would have been one thing to just connect everything together and read some pressure signals, but making sure we had all the software redundancies in every corner case, and working through the potential failure modes was a much bigger challenge," he comments. "Part of that was to ensure that Robert could still achieve 1G braking, even without the system's assistance. That made the mechanical design quite tricky too. There's only so much grip strength that a person can generate, so we spent a lot of time sizing master cylinders." ▶

ABOVE The goal for the journey was for Wickens to get exactly the same feeling that team-mates do from their hydraulic brake system, but through his hands

BELOW The six buttons below are standard; the Bosch magic sits above, with a toggle between foot- or hand-operation for each driver, plus brake bias settings and buttons that enable Wickens to vary the amount of assistance he receives



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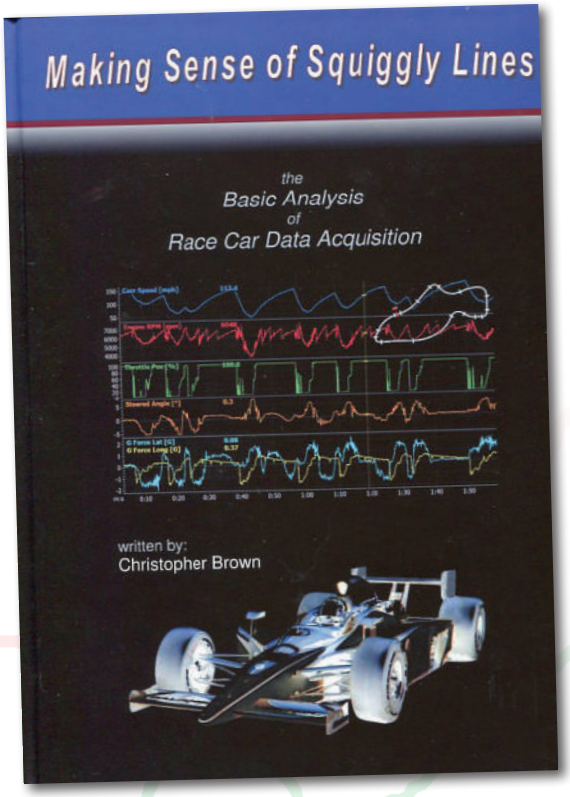

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> *It's really cool to make racecars go fast. But to have an effect on the human side and unlock someone's full potential – it doesn't get much better than that"*

ABOVE Jordan Krell, senior motorsport engineer at Bosch Motorsport, explains that the human element made the project an incredibly rewarding one for the whole team

With the passive system used previously, the team had found that pressure response could vary substantially from one corner to the next due to the mechanical backlash in the linkage. Another inherent challenge with hand control systems is relaying feedback. A driver operating a master cylinder with their foot can achieve 100+ bar line pressure, whereas the pressure going through a hand control master cylinder is in the region of 8 bar. Consequently, subtle changes can be much harder to detect, so every effort has been taken to minimise backlash and improve precision.

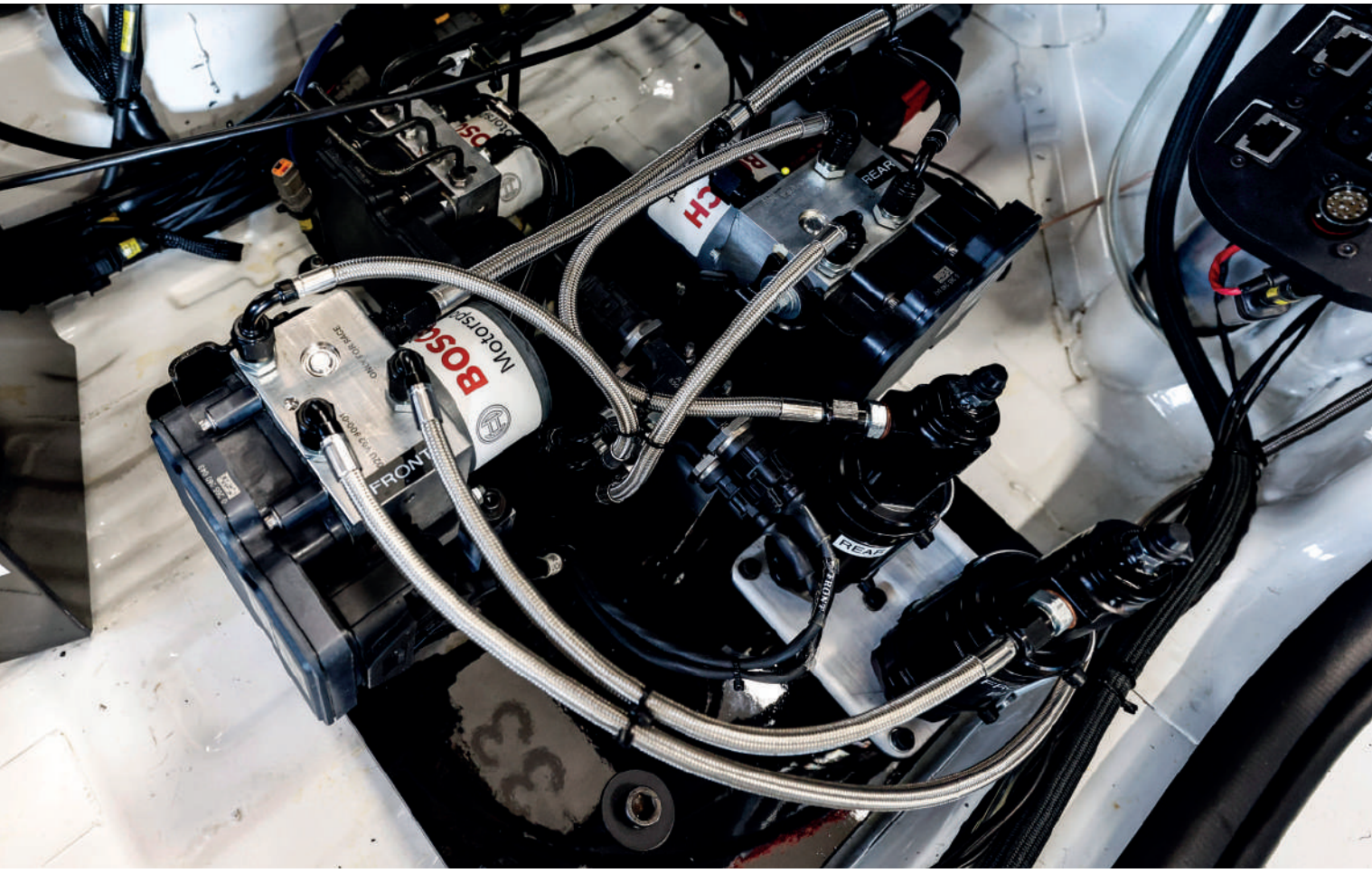
Unexpected benefits

Interestingly, this has also had an impact for Gottsacker, Krell explains: "It had been two years since Harry [Gottsacker] had driven a TCR without a set of mechanical linkages attached to the column. He commented that the pedal on the new car was firmer and more responsive. That isn't normally what you expect to hear when more plumbing has been added to a brake system, but it no longer has the linkages going to the column, and we've removed a lot of other pieces in the brake system."

Outside of this project, Bosch Motorsport's EBS module is perhaps best known for being used as part of the spec hybrid system on the LMDh cars. The concept is quite different here, as is the plumbing, but the EBS hardware is carried over without any changes and the control software has only been lightly modified, Krell explains.

"There were a couple of calibration parameters that we had to change for

BELOW The display shows the health of the entire system. It is blank during the race itself, to avoid distraction, but can still flash immediate warnings should a problem occur



the different pressure range [compared to a foot-operated system], but aside from that, it runs the same base software as LMDh," he notes.

This project has already provided insight that can be fed back into other applications for the EBS, Krell explains. In particular, improving robustness and software algorithms. It's also paved the way to making the system itself more accessible.

"There's a whole team at Bosch that made this happen," he comments. "Going through all the safety cases; making sure that we got the feel right. That's a big engineering effort that requires significant resources. We see this moving forward to a much more accessible point, where it's more like buying an ABS kit and installing it in your car. The big lessons in this project come back to making it a really safe, robust system with all the use cases understood."

The system's modular nature means the technology can be used again in the future.

The market is certainly there. While safety has improved dramatically over the years, it remains a sad irony that the people drawn to active sports, from horse riding to motor racing, are often those most likely to sustain life-changing injuries. Not to mention scores of people living with existing conditions that have so far proved a barrier to taking part in motorsport. Opening up access to hand controls in motorsport is surely something that would change lives.

"It's really cool to make racecars go fast," accepts Krell. "But to have an effect on the human side and unlock someone's full potential – it doesn't get much better than that."

Wickens is quick to note that this innovation is as much about others as himself.

"As a selfish race driver I want to go as fast and as far as I can," he says. "But hopefully when I'm done with my career, I can hold my head up high for creating an easier path for the next generation of disabled motorsport athletes trying to find their way to the highest levels of motorsport.

"I'd love that: to be able to show that injury doesn't have to define who you are. If you want to be a racecar driver, go be a racecar driver..." RT

ABOVE Wickens' brake feel simulator. Marked front and rear these are, for want of a better word, he says, two "springs" that give the feedback he needs to feel the system

BELOW Bosch Motorsport's EBS module is best known for its role in the spec hybrid system on IMSA's LMDh cars

THE *INVISIBLE* ENGINE!

Chris Pickering examines the 5.5-litre naturally aspirated V8 which demonstrated speed and 100 per cent reliability for Corvette's first foray into customer racing

LIKE Bob Dylan plugging in his electric guitar in front of a stunned crowd of folk fans or David Bowie morphing into Ziggy Stardust, the launch of the Corvette C8.R in 2020 was a watershed moment.

Gone was the classic muscle car soundtrack of a crossplane crank V8, along with the iconic front-engined silhouette. The brand that had carved its own niche since 1953 had changed forever.

The GTE-spec C8.R was subsequently offered in GT3 form, courtesy of an update pack. But it wasn't until the arrival of the Z06 GT3.R earlier this year that we saw a mid-engined Corvette that had been designed as a GT3 car from the outset. With it came a new 5.5-litre naturally aspirated V8, which draws more from the LT6 production engine than the old LT6.R race unit.

The GT3.R also marks a fundamental shift in the way that the C8 is going racing, as GM Corvette engine programme manager Saverio Leone explains.

"In the past, we've sold cars after the factory effort and supported customers who wanted to take them racing in certain series. But this is our first full foray into customer racing," he comments. "All the teams racing the Z06 GT3.R, including Pratt & Miller [which previously ran Corvette's works race teams] are now customer teams, which has changed how we approach things."

One of the key concerns in customer racing is cost control, which links directly to reliability. This left the GM engineers with a dilemma, given that they already had the well-proven, but somewhat more exotic LT6.R engine on the shelf.

"Our initial thoughts were to continue running the LT6.R," recalls Leone. "It was a great engine, which was already known to be reliable. In the end, it wasn't so much the constraints of the technical regulations but the spirit of the GT3 category that steered us to remain as close as possible to the production engine. The production team has done an incredible job of designing and producing what's essentially a race engine for the street, so that made our job a lot easier."

While the old LT6.R pushed the race engine development further, the two powerplants are based around the same fundamental architecture. Both are double overhead cam V8s with flat plane crankshafts. They share the same bore and stroke dimensions, and the same cylinder heads. The key difference is that the majority of the internal parts – notably, the pistons, rings, connecting rods and crankshaft – now come straight from the production car, whereas the C8.R used bespoke motorsport items.

> *"From a manufacturer's perspective, it's great to be invisible"*

The induction systems are quite different as well. On the C8.R, the system was fed from a scoop on the top of the engine cover, then channelled into a bespoke carbon fibre air box with individual throttle bodies and motorsport-specific intake runner lengths. In line with the production-based GT3 regulations, the Z06 GT3.R feeds from the stock air intake near the passenger door and retains the standard manifold and its twin throttle body layout. In total, around 80 per cent of the engine is now taken straight from the production line in Bowling Green, Kentucky, where the road-going Z06 engines are produced.

"GT3 is very much a production-based category, ▶

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LAT Images/IMSA

ABOVE The GT3 project has required a fundamental shift in Chevrolet's approach, with its 5.5-litre naturally aspirated V8 drawing 80 per cent of its parts from the production line

so that drove a lot of the design direction. With a customer car you also need to keep the price of the components very much in mind, and using production parts really helps from that perspective," notes Leone.

While the parts are indeed taken from the production line, there's more to the build process than plucking a ready-built engine from the factory, he explains: "I'll call the factory and say I need perhaps 25 engines. Those are shipped straight off the assembly line, but then we fully disassemble them. We do a little extra deburring and cleaning and things like that. And then we reassemble with some new or modified components."

The changes to the core structure of the engine are minimal. In the GTE days, manufacturers were allowed to machine off unused bosses on the engine and suchlike, but now the block must remain essentially standard and there are strict weight limits for all the other components.

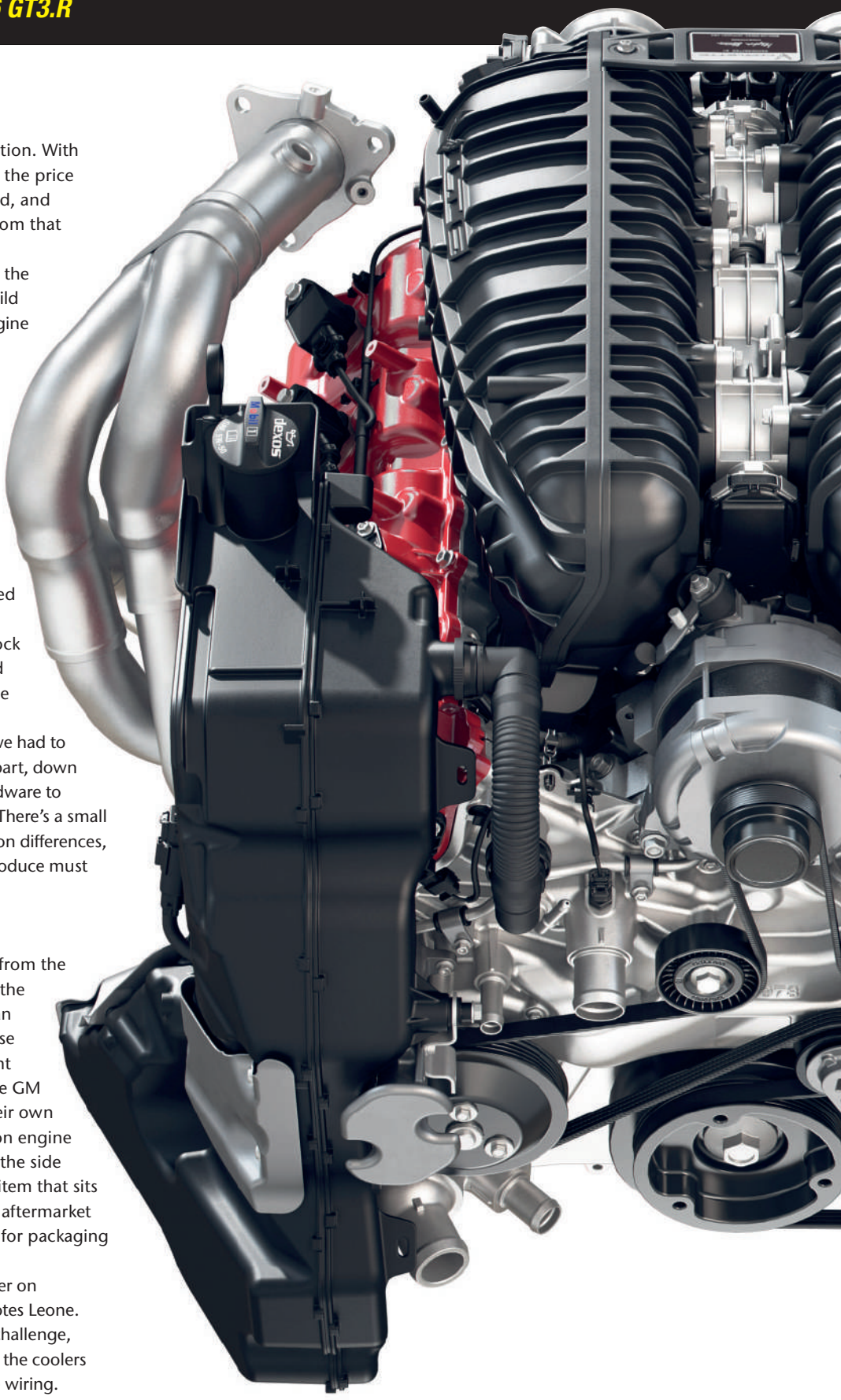
"During the homologation process, we had to tear down an engine and weigh each part, down to individual valve springs and the hardware to mount the exhaust," explains Leone. "There's a small tolerance on that to allow for production differences, but fundamentally every engine we produce must meet those homologated weights."

Packaging challenges

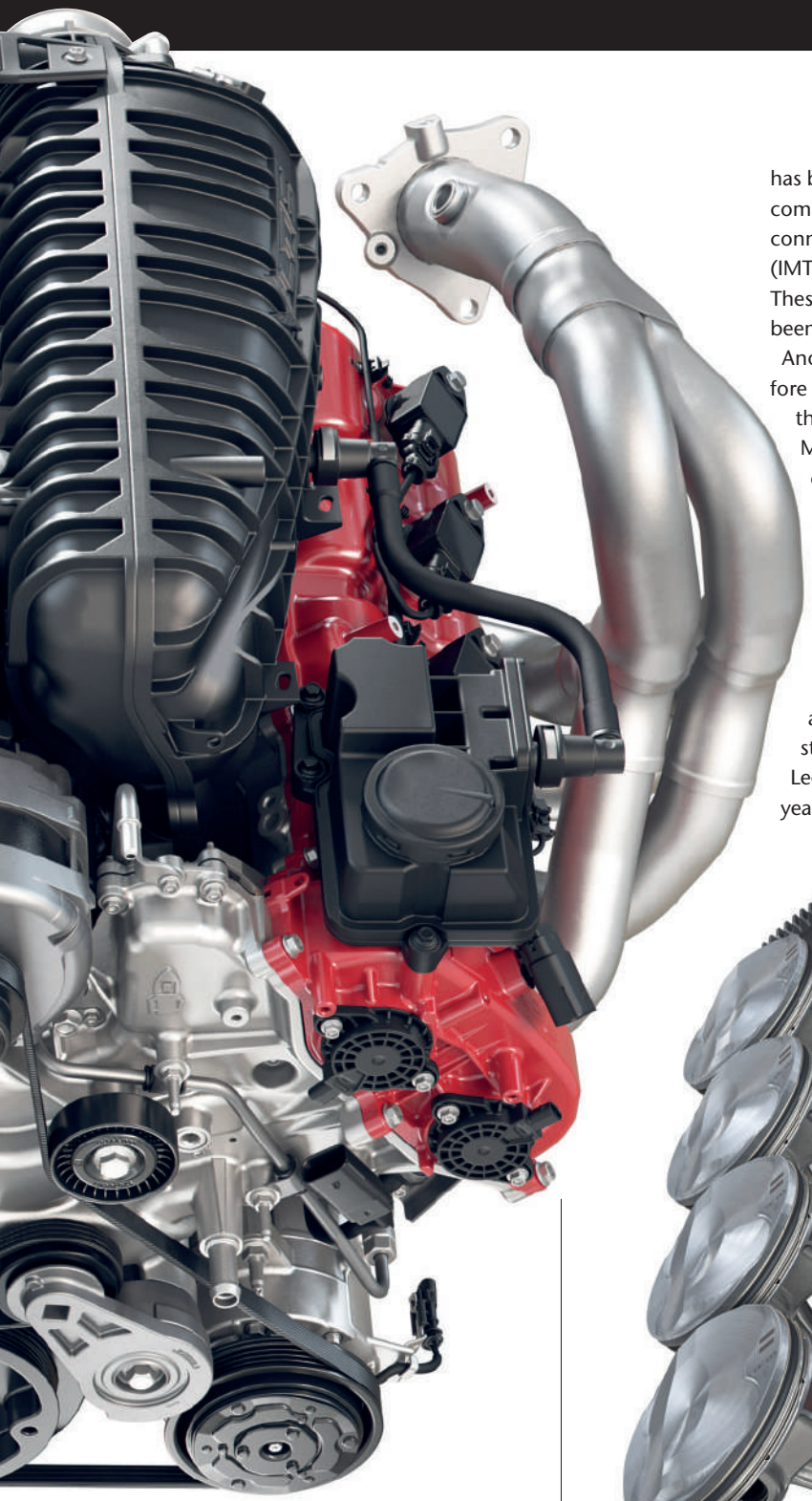
The biggest differences actually stem from the engine location in the racecar, where the V8 sits lower and further forwards than in the production machines to optimise the centre of gravity height and weight distribution. To make this possible, the GM Motorsports engineers had to cast their own sump and front cover. The competition engine uses a custom oil cooler mounted on the side of the block, in place of the standard item that sits below the production car's sump. An aftermarket racing oil pump is also used – largely for packaging reasons with the new sump.

"Typically, mid-engined cars are tighter on packaging than front-engined cars," notes Leone. "The routing also becomes more of a challenge, when you're deciding where to mount the coolers and how to route the fuel lines and the wiring. Another thing is that you've generally got less air flow through the engine compartment on a mid-engined car, so thermal management becomes more of a concern. Fundamentally, the engine doesn't care where it's mounted on the vehicle, but it does have an impact on the components and the accessories."

The only real changes to the durability of the base



> *"We've had incredibly low oil consumption: we did the whole Le Mans race without topping up"*



has been simplified too. The intake system for the V8 is essentially comprised of two plenum chambers. On the road car these are connected by valves, known as the intake manifold throttle valves (IMTVs), which improve the low-speed running of the engine. These aren't required for the rev range used in racing, so they've been removed for the sake of simplicity.

Another area where the Corvette's simplicity comes to the fore is the use of a naturally aspirated powertrain. Around half the GT3 grid – including the latest offerings from Ferrari, McLaren and Aston Martin – now use twin-turbocharged engines, but the Z06 road car remains naturally aspirated, which means that the GT3.R follows suit.

At 5.5 litres, the simple fact is that the Corvette's V8 can easily make the GT3 power targets without the use of forced induction. In road-going trim, the naturally aspirated Z06 engine makes 670 hp, whereas the GT3 target typically varies from 500 to 520 hp depending on the circuit.

"The series has done a really good job of balancing naturally aspirated and turbocharged cars, but from our perspective it's still easier not having to deal with turbocharging," comments Leone. "Our first real foray into GT3 racing at GM came a few years ago with the Cadillac ATS-V.R, which used a twin turbo ▶

LEFT & RIGHT The majority of the internal parts, notably the pistons, rings, connecting rods and crankshaft, come straight from the production car's LT6 V8

engine come from the connecting rod bearings, which are replaced with tri-metal motorsport items, while the main bearings on the crankshaft remain stock. The cam phasers are also removed to provide fixed cam timing on the competition engine, which reduces weight and complexity, and simplifies the oil control around the camshafts. The production chain drive and tensioners are still used, just with the phasers changed to a fixed sprocket.

There are other areas where the engine

Photos: LAT Images/IMSA

engine and it was very challenging. You had to hit a boost limit target, which is a control challenge, and we also struggled with the heat management. Now the regulations in the WEC are based around torque sensors and they're about to introduce that in IMSA too, so we already have a torque limit we have to follow. Having a boost limit to control at the same time would only add to the complexity."

Despite this, Leone says that the biggest technical challenge in the project has still been the control systems. In addition to the closed loop torque control function integrated into the Bosch MS6.4 ECU, the car also features an electronically-controlled clutch and paddleshift system.

"I think we've had enough years of experience to build a strong engine in terms of hardware. But as things progress, the control strategies have become really technically challenging. Our control structure is based on a production concept called a torque-guided structure. That's basically a torque model within the ECU, and that's quite different to what we've typically run in the past."

Durability testing

When Leone and his colleagues began evaluating the option of a more production-based engine for the new GT3 car, their first step was to put an unmodified road car unit straight onto the dyno. Lap data from Le Mans was used to generate a script for the dyno, which was then subjected to 100 hours of durability testing.

> *"When we first put the production engine on the dyno, we were thinking, 'Oh boy, what are we going to break here?' It surprised us how little we needed to do"*

ABOVE The Corvette Z06 GT3.R's first win was at the track traditionally known as Mosport, where the Pratt Miller team dominated from start to finish

"Our durability target was to do a full WEC season [between rebuilds], which is around 20,000 km," explains Leone. "We started with a 30-hour durability test, which equates to around half of that target. Then we tore everything apart, checked everything, changed a few items, basically just played with some clearances. And then once we were able to do that, then we stepped into a full 100-hour test. After that, we tore it down again, inspected it, and had the production team come over to take a look, as it's basically a production engine. At that point, we were confident that we could do 20,000 km of racing without having to change very much on the base engine."

While it wouldn't be entirely fair to say that money ▶

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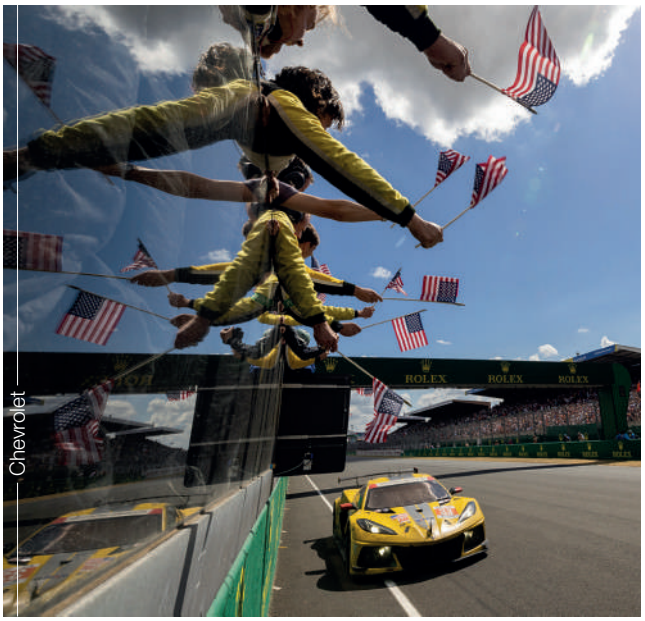
Chevrolet

was no object in the old GTE engine, it was certainly less of a concern than it is with a customer-focused GT3 car, Leone recalls: "The budgets are a lot higher for a factory GTE effort. The crankshaft was probably the biggest difference. We used a Pankl crankshaft in that engine and it was a beautiful piece of art. But we've spent a lot of time testing the new engine and it's performing just as well with the production parts."

It's partly thanks to improvements in the design of the production crank, pistons and rods that the motorsport engineers have been able to do this, Leone notes: "The production team did a phenomenal job of oil control through the engine. That can be one of the biggest challenges in a race engine, so that made our life easier. And the balance of the crankshaft and the rotating assembly in a high-revving flat-plane engine is critical in the design and they did a fabulous job on that too.

"We do suffer from some vibration challenges, which are just inherent in a flat-plane V8. We solidly mount the engine in the car, whereas the production team utilizes engine mounts that pick up the vibration, so that's been a little bit of a challenge for us. But we actually rev the engine a little bit less – our rev limit is restricted to 8,000 rpm, while the road car can go to 8,600 rpm. So far, we've had zero issues. One of the things we noticed is that we've had incredibly low oil consumption – we did the whole Le Mans race without topping up the oil, which was great."

The reliability experienced by the GT3.R is by no means a given with a production-based engine, and Leone admits to a degree of trepidation when the project began: "The duty cycle in racing is very different to a road car, even one that's driven hard, so when we first put the production engine on the dyno, we were thinking, 'Oh boy, what are we going to

ABOVE The old C8.R (seen here taking the marque's ninth class win at Le Mans) had quite a narrow performance window, which the works drivers could handle. The customer GT3 offering has been developed from the start to be more driver-friendly

ABOVE RIGHT Corvette Racing is IMSA's most successful team across its 25-year involvement in the series, but it faces tough opposition in the GTD ranks

DPPI

LEFT The FIA World Endurance Championship campaign ended on a high, with TF Sport's Corvettes finishing second and third in class in the Eight Hours of Bahrain

LAT Images/IMSA

break here?' It really surprised us how little we needed to do."

One particular area of scrutiny was the valvetrain, he explains. Not only is there a constant stream of acceleration and deceleration at high revs in a race engine, but also some very abrupt ignition cuts from the gearshift system and the traction control. Items such as the valve springs and cam followers can take quite a hammering.

"Initially, we were a little concerned about the finger followers," Leone recalls. "But that was during very early testing. We called in our production team, they took a look at it, and they said it was fine. So, it was just more becoming familiar with the components and understanding them. The duty cycle may be different, but they probably run twice as many hours on their durability tests. After that, we kept pushing it and discovered that the limit was much higher than we thought."

> *"Our durability target was to do a full WEC season, which is around 20,000 km"*

Biggest compliment

The GT3.R engine has gone on to prove itself in competition, with a 100 per cent reliability record over its first season in IMSA and the WEC.

"From a manufacturer's perspective, it's great to be invisible," jokes Leone. "I was talking to the crew chief of one of our customer teams at the COTA WEC race when it was very hot back in the summer. The water temperatures were up to 108 deg C, which is warmer than we'd like and I asked if they had any concerns. His response was, 'I don't ever think about this engine, all season'.

"As a powertrain engineer, that's the best compliment you can get. There are a lot of challenges for a team adapting to a brand-new car, and if they don't have to worry about the engine, they can focus on everything else. I think that's what I'm most proud of with the introduction of this car."

Victory in Ontario and podiums at several other events in IMSA's GTD Pro category for Pratt & Miller, not to mention TF Sport's second place finish in the final WEC round of the season in Bahrain have demonstrated the new Corvette's capabilities. It's been a solid start for the Z06 GT3.R. Even if we do still sometimes miss the thunderous soundtrack and the sheer swagger of the old front-engined charger. RT

SAVED!

450 tonnes of CO2
$0.5 million in fuel
$10.0 million in tyres
$1.5 million in crash repairs

Can simulators *really* aid racing's quest for Net Zero? Have a look at the figures a top-tier manufacturer revealed to Race Tech, and decide for yourself. By **Chris Pickering**

RIGHT Featuring 9DOF with 5m XY travel, Dynisma's new DMG-360XY simulator has already attracted orders from multiple F1 teams

THERE'S a huge sustainability challenge at the very heart of motorsport. And it's not what you might think. For all the shock and awe generated by a grid full of Formula 1 cars, their tailpipe emissions account for less than one per cent of the series' total carbon footprint. By far the greatest impact comes from transporting people and equipment around the globe.

Each car is shipped around 75,000 miles during the course of a season – that's equivalent to circumnavigating the earth three times. In total, travel and logistics account for more than 70 times the emissions of the fuel burnt on track.

That makes transporting the Formula 1 circus an expensive business, and it applies equally well to testing. Back in the days before mileage limits and budget caps, teams could clock up as many as 70 days a year track testing. Now they're limited to just three pre-season days and a couple of hundred kilometres of in-season running, ostensibly for promotional purposes.

Tyre usage has been slashed too. At the height of the Formula 1 tyre wars, drivers would do two flying laps on a qualifying set before changing them and going straight back out. The process would be repeated for hours on end at a test day.

This transformation has been largely enabled by a greater reliance on simulation. Before each round, a Formula 1 team will clock up something like 500 laps of virtual testing using a Driver-in-the-Loop (DIL) simulator, not to mention scores of CFD runs and other offline simulations.

"Simulators are becoming more and more useful not just as a driver training tool but as an engineering and set up tool, with less testing available the teams now have to hit the track with the car dialled in immediately if they are to be competitive. This reduces the need for physical testing, leading to substantial savings in both cost and carbon footprint," comments Simon Holloway, Commercial Director at Dynisma.

From a sustainability perspective, virtual testing wins hands-down. According to data from Dynisma,

a professional-grade simulator might consume 20 kW. Simulating a 90-second lap of the Barcelona circuit (equivalent to LMP2 or Formula 2 pace) therefore equates to 0.5 kWh of energy usage (0.025 hours x 20 kW). In the UK, electricity from the grid averages out at 0.207 kg of CO2 emissions for every kWh generated, hence the simulated lap emits the equivalent of approximately 0.103 kg of CO2 (0.207 kg/kWh x 0.5 kWh). For comparison, a real-world lap at that pace would consume around 2.1 litres of fuel, which equates to 4.86 kg of CO2 (based on the EIA's figure of 2.3151 kg per litre). That's a reduction of 98 per cent.

Multiplied out over the course of a season, the figures become even more compelling. Based on simulator usage figures publicly released by one of the front-running Formula 1 teams in 2021, Dynisma calculates that the team accrued approximately 24,500 laps of simulator time over the course of a season or 82,000 miles.

To achieve the same distance in real world testing would consume roughly 51,500 litres of fuel (based on simulated fuel consumption data from the Circuit of The Americas, which sits close to the average length of a Formula 1 track). That equates to 119 tonnes of CO2. Assuming a reduction of 98 per cent, ▶

using the simulator would save nearly 117 tonnes of CO2. Furthermore, multiplying that distance over a two-stop race (i.e. three sets of tyres) gives 1,300 sets of tyres.

In the case of many OEMs, it's more than just one series. According to Dynisma, another top-tier manufacturer has calculated that it clocks up 250,000 miles of simulator testing annually across all its motorsport activities. We'll save you the sums this time, but the company estimates that carrying out the same testing in the real world would equate to 450 tonnes of CO2, $0.5 million in fuel, $10.0 million in tyres and (statistically) $1.5 million in crash repairs.

Controlled conditions

Testing in the virtual world isn't just cheaper and more sustainable than shipping the cars to a track, it also offers far greater control. The simulated track, tyre and weather conditions can be set exactly as required, with absolute repeatability from one run to the next, making it easier to compare setup changes. There's no danger of traffic getting in the way or stoppages due to mechanical failure, and a vast array of different car configurations can be evaluated at multiple circuits without ever leaving the room.

The same could be said for other types of virtual testing. Offline lap simulations, for instance, can be run significantly faster than real-time, allowing even more combinations to be evaluated. In many cases, however, the human aspect is a vital part of the puzzle.

When engineers began developing commercial lap simulation packages in the 1990s, they noticed a curious thing. Beyond a certain point, they could keep improving the physics of the vehicle simulation, but it failed to have a significant impact on the accuracy of the lap time prediction. What was – and still is – missing was the behaviour of a human driver.

Professional racing drivers are some of the most accomplished all-round athletes in the world, but they're still human. They require detailed feedback to understand what the car is doing and time to process that information and react. A setup that's too twitchy for a human driver's reaction times or one that fails to ▶

BELOW A lap of the Circuit de Barcelona (4.657 km) in real-world testing would result in 4.8 kg of CO2 emissions, while the same lap in a Dynisma simulator results in just 0.1 kg – a 98% reduction per lap

> *"Add an extra 50 milliseconds and you're effectively delaying a professional athlete's reaction times to those of a middle-aged club racer"*

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instil confidence in the car will be slower nine times out of 10, even if it's theoretically superior to a more driveable setup. It's this fallibility that makes it so useful to put a driver in the loop.

"You need a car that the drivers can actually drive, which is where DIL comes in," comments Holloway. "The systems can very accurately replicate things like how to bring a tyre into its performance envelope. A good example being the World Endurance Championship (WEC) and the banning of tyre warmers. Hitting the track straight from the pit lane on a set of cold tyres, having just been driving on a set of hot tyres, takes some practice. Particularly for a bronze driver, it can be tricky to go through that transition and still get the best performance."

Simulators have become an essential tool for circuit familiarisation and driver development. It's now common for F1-affiliated Formula 2 drivers to spend time in the F1 simulator on non-race weekends to help them prepare for the next step up. A growing number also have some degree of e-sports experience before they reach the professional teams, even if it's only a PlayStation from their karting days.

"With the higher levels of motorsport now using simulators more and more, it is becoming more important for junior drivers to understand the benefits of simulators and be comfortable using them. As they climb the ladder in their career, they will be expected to use them more and more," notes Holloway.

> *"Fooling the human brain into believing that it's hurtling into Eau Rouge at 189 mph rather than sitting in an industrial unit in the Midlands is a formidable challenge"*

ABOVE Previously, commercially available motion simulators, particularly those that were affordable to anyone outside of F1, lacked the realism to replace real world testing. Dynisma CEO Ash Warne is on a mission to change that

BELOW With track testing so restricted and the cost cap biting, teams are increasingly using simulation rather than droning around a deserted racetrack

Ferrari

Evolution

The benefits are clearly there, but unlocking them depends on the accuracy and accessibility of DIL simulators. Fooling the human brain into believing that it's hurtling into Eau Rouge at 189 mph rather than sitting in an industrial unit in the Midlands is a formidable challenge. The driver needs to be totally immersed in the experience to deliver responses that are representative of the real car. This involves everything from the design of the cockpit environment to the quality of the audio, but the hardest thing to mimic is movement.

Simulators can't generate the full range of sustained forces that you experience in real world driving, but what the best motion platforms can do very well is represent the key changes, such as the onset of oversteer or understeer. According to Dynisma's CEO Ash Warne, the principal factors in communicating this motion are latency, bandwidth and smoothness.

"Our key innovation has been reducing latency from 25 to 50 milliseconds to under 5 milliseconds," he comments. "That allows drivers to respond quickly to motion cues, maintain accurate control at the limit of grip, and handle oversteer and balance more precisely. Increased bandwidth provides better motion ▶

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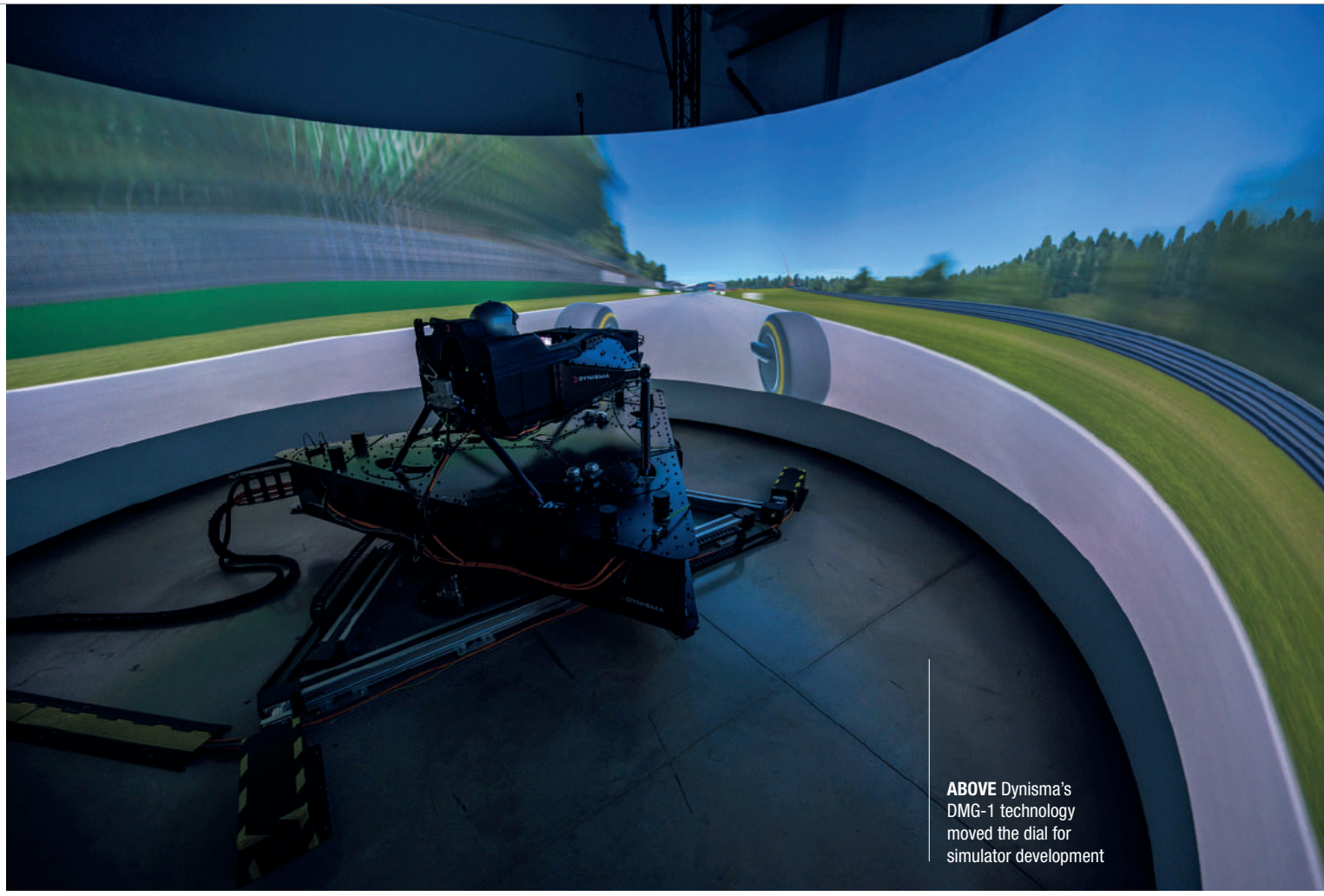

ABOVE Dynisma's DMG-1 technology moved the dial for simulator development

definition and resolution, while supporting large excursions for fast, accurate feedback."

Even the slower end of this spectrum lies well below human reaction times, which range down to about 150 milliseconds for an elite-level racing driver. But that doesn't mean they're imperceptible. Add an extra 50 milliseconds and you're effectively delaying a professional athlete's reaction times to those of a middle-aged club racer. It's not unknown, Warne points out, for teams to dial in extra understeer in the simulator setups because the world's best drivers struggle to control them.

Bandwidth is the range of frequencies that the motion platform can reproduce, from high frequency ride content through to low frequency changes, such as body movement. Smoothness, meanwhile, is a question of eliminating sources of coarseness and mechanical or electrical noise, which can otherwise make the motion feel granular. It's these three factors that mark out a simulator fit for vehicle development and setup rather than just basic tasks such as circuit familiarisation.

Accessibility

The high-end simulators used in environments such as Formula 1 have made significant strides in recent years, but Holloway predicts that one of the trends will be increasingly accessible systems available to lower levels of the sport.

> *"Travel and logistics account for more than 70 times the emissions of the fuel burnt on track"*

"It's likely that we'll see the dissemination of the F1-derived technology down into the lower tiers of motorsport," he comments. "Many drivers at all levels already use gaming rigs and simple set ups to learn the track before they arrive, and even F1 drivers are known to race in e-sports to keep sharp when they are not in the car itself. As full motion simulator technology becomes more readily available and can be used as an engineering tool, the uptake in lower formulas is likely to increase as teams embrace the benefits of car development in the virtual environment."

Investing in a simulator on-site at their facility can help teams and manufacturers develop vehicle models, tyre models and setups. It's likely that most who can afford to do so will go down this route, Holloway believes. However, he also predicts the rise of more 'simulator as a service' facilities where teams can use professional simulators without the capital investment.

"Sim as a service is a very affordable route in for teams who may later decide to buy their own

ABOVE RIGHT When Dynisma CEO Ash Warne was tasked with focusing on sustainability at last year's WMS, his research uncovered some startling figures when OEMs began crunching the numbers

RIGHT Dynisma's disruptive technology, generating £11.9m of simulator sales and growth of 78.86%, catapulted it into The Sunday Times 100, ranking Britain's fastest-growing private companies. The Bristol-based outfit's new tech campus was fully operational by Q1 2024

simulator. It also allows the team to leverage the expertise of an experienced simulator team," he comments. "We already offer time on our demo simulators for teams wishing to see the benefits as well as gaining the knowledge from our simulation team, many of whom have run simulator programmes in F1 and other high levels of motorsport."

All things are relative, of course, and a simulator will remain a substantial upfront investment. However, professional-level teams and manufacturers are already likely to have most of the data required for the simulator, and quite possibly a complete vehicle model used for other forms of simulation.

"Our motion platforms are software agnostic, integrating with any of the commonly used vehicle simulation tools," he comments. "This means the team doesn't need to completely change their existing software suite to use a Dynisma simulator. If the integration does not already exist, we will work with the customer and the supplier to integrate the software and obtain the best results from that integration. We also often help customers with their own models if they don't already have that experience."

The fact that most teams will already have the basis of a good vehicle model returns to the sustainability argument. Existing data can be used to build and correlate the model, meaning that there's no additional carbon cost, beyond the small amount of energy used to power the computers and the simulator.

A small amount of physical testing is always likely to remain useful, as with Formula 1's sole three-day test. But it's the use of simulation that has allowed this figure to be slashed from 50+ days of in-season testing at the height of the 1990s tyre war. Proof that sustainability benefits can come from the most unexpected places. RT

INGENUITY IS BACK IN F1!

The budget cap took the rap for Red Bull's speed deficiency at Las Vegas. You don't have to be a gambler to bet how much sympathy that excuse elicited from **Sergio Rinland**

IN December 1991, when Lap Simulation was in its infancy and DiL simulators not on anyone's radar, my company Astauto was hired by Fondmetal, a back-of-the-grid Italian team, to design and build their 1992 Formula 1 challenger. (Not 1993, *1992*!)

A bit late to start designing a car for the year after, you would say. If you were a fan of understatement. We moved to new offices on January 2nd, 1992, took the first two weeks to adapt the newly-acquired Ford Cosworth HB engine to the 1991 Fondmetal, then we started to pen the 1992 car. It saw the light at the Fiorano track only four months later, so its first race was the Canadian GP in June.

Saying that Fondmetal was underfinanced is another understatement. The year when Williams used 60 underfloors (at the time a consumable!), we had three: one for each of the cars we built. But, we had the luxury of a wind tunnel (the Yamaha facility previously of Brabham) and two wind tunnel models; we knew where to spend our limited resources!

We had, of course, three aerodynamic set ups: medium downforce (Silverstone, Barcelona); low downforce (for perhaps Spa and certainly Monza); and high downforce for Hungary. (We knew we would miss Monaco with the new car, but that still left one high-downforce race.)

When we designed the low-downforce wings, a small rear wing and trimmed off front flaps, the wind tunnel results showed us we had the right aero. But, when we got to Monza, with the trimmed front flaps at minimum, we had too much downforce at the front (not ideal for the Lesmos!) and we could still trim the rear wing to gain straightline speed, master at Monza.

What to do? We had to use our ingenuity, so we decided to 'kill' the front wing ground effect by bonding two small Gurney lips on the underside of the main wing element. That way, we could achieve the aero balance we wanted for the minimum rear wing. Good old days! Haha.

That anecdote came to mind while watching the Las Vegas Grand Prix weekend when we saw Red Bull struggling with straight line speed (7 kph deficit!). Being what F1 is today, where it is very difficult to hide, Helmut Marko said, "We don't have a low downforce rear wing here."

I was astonished. In this day and age, with state-of-the-art DiL simulators with a dedicated driver at base and offline lap simulators where they can simulate a few hundred thousand scenarios overnight, how could RB not know what they needed for Las Vegas?

Max Verstappen said that after Monza, due to the restrictions on the budget cap, they had to prioritize their expenses over aero setups for high-speed circuits (Monza and Las Vegas).

Going back to 1992, so short of money was Fondmetal that they did not finish the season, so our car did only seven races. Their budget (at today's rate) would equate to 'pocket money' even for a team like Haas or Williams. How can this be possible that a team like Red Bull sacrifices two races for the sake of a small rear wing? Risking losing the all-important Constructors' Championship? At least Verstappen managed to clinch the Drivers' Championship with pure talent.

As events transpired, between Friday and Saturday Red Bull engineers resorted to trimming the rear flap to recover some straightline speed. I am glad that ingenuity is still part of the current high technology and clinical Formula 1!

BELOW The design of the Fondmetal GR02 for 1992 began… in 1992!

BOTTOM Red Bull was hampered by budget cap. Hmm…

> *"When they can simulate a few hundred thousand scenarios overnight, how could Red Bull not know what they needed for Las Vegas?"*

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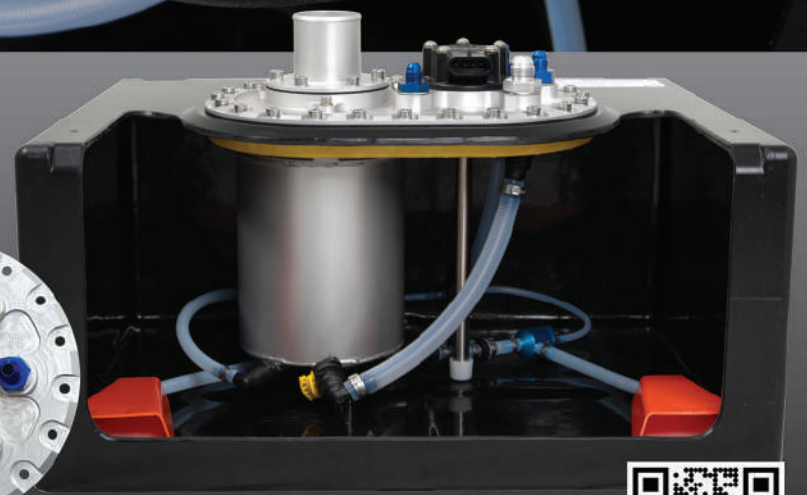

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